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Computer-Aided Structural Engineering (CASE) Project

User's Guide to CTWALL – A Microcomputer Program for the Analysis of Retaining and Flood Walls

by Michael E. Pace

Prepared for Headquarters, U.S. Army Corps of Engineers

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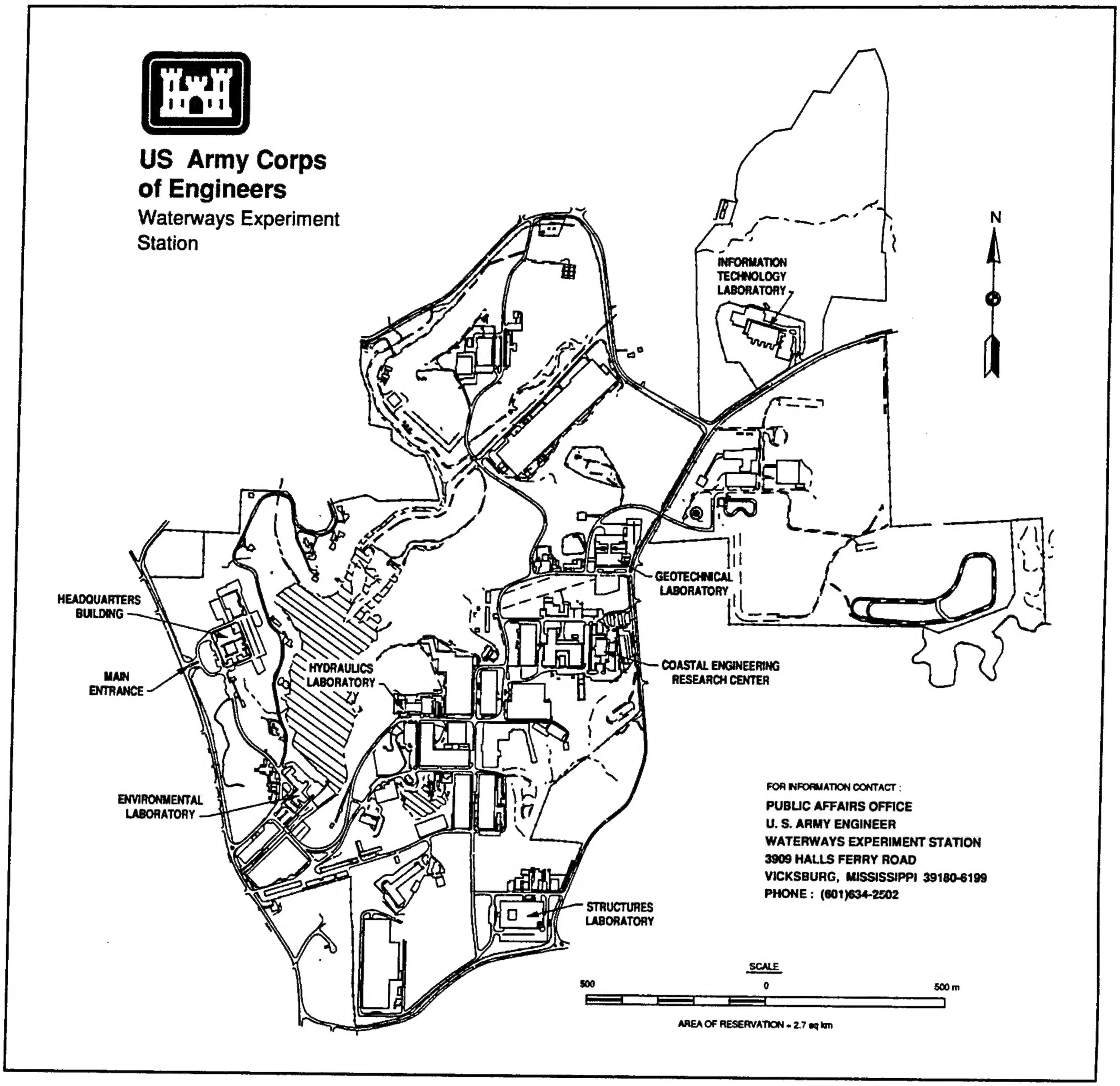

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Contents

Preface

This report documents CTWALL, a computer program that assesses the stability of T-type retaining and floodwalls. Funding for the development of the program and publication of this report was provided to the Information Technology Laboratory (ITL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, by the Civil Works Directorate, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under the Computer-Aided Structural Engineering (CASE) Project.

Specifications for the program were developed by members of the T-Wall task group of CASE. Members during development of the program were:

Mr. Byron Bircher, CEMRK-ED-D
Mr. George Henson, CESWT-ED-DT
Mr. Clifford Ford, CESPL-ED-DB
Mr. Scott Snover, SCS
Mr. Tom Wright, CEMRK-ED-DS
Mr. Raymond Vaselka, CESWD-ED-TS
Mr. Donald Dressler, CECW-ED
Mr. Lucian Guthrie, CECW-ED
Mr. Bill Price, WES
Mr. Mike Pace, WES

The computer program and user's guide were written by Mr. Michael E. Pace, Computer-Aided Engineering Division (CAED), ITL, WES, under the general supervision of Mr. H. Wayne Jones, Chief, Scientific Engineering Applications Center; Dr. Reed L. Mosher, Acting Chief, CAED, and Dr. N. Radhakrishnan, Director, ITL. Mr. Donald Dressler was the original HQUSACE point of contact, and Mr. Lucian Guthrie is the present Technical Monitor.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
kips (1,000 lb mass)	453.59237	kilograms
kips (force) per square foot	47.88026	kilopascals

1 Introduction

Purpose of Program

The purpose of CTWALL[1] is to assess the stability of T-type retaining and floodwalls in accordance with EM 1110-2-2502[2] and ETL 1110-2-322.[3] CTWALL will assess the overturning and sliding stability of a retaining or floodwall in accordance with the aforementioned criteria documents.

Organization of Report

The remainder of this report is organized as follows:

a. Chapter 2 describes the installation and equipment requirements of the program.

b. Chapter 3 presents a general overview of the operation of the program.

c. Chapter 4 discusses the interactive operation of the program.

d. Chapter 5 describes the capabilities of the program.

e. Chapter 6 describes the procedures used in performing the stability analyses.

f. Chapter 7 is the input guide. This section will explain the format to be used for a data file and will also explain the input variables and some data restrictions which apply to input from a file or from the terminal.

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1 CTWALL is designated as X0153 on the Conversationally Oriented Real-Time Programming System (CORPS) Library.

2 Headquarters, Department of the Army. (1989). "Retaining and Floodwalls," Engineer Manual 1110-2-2502, Washington, DC.

3 Headquarters, Department of the Army. (1990). "Retaining and Floodwalls," Engineer Technical Letter 1110-2-322, Washington, DC.

g. Appendix A contains a set of examples taken from EM 1110-2-2502, ETL 1110-2-322, and the CSLIDE user's guide (IR ITL-87-5).[1]

h. Appendix B describes the features of the program which the user can customize for their particular needs or preferences.

i. Appendix C describes the operation of the text editor available within CTWALL.

j. Appendix D describes the operation of the utility equations contained in CTWALL. The utility equations are interactive equation solvers for several of the equations contained in EM 1110-2-2502 and ETL 1110-2-322.

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1 Pace, M. E., and Noddin, V. R. (1987). "Sliding Stability of Concrete Structure (CSLIDE)," Instruction Report ITL-87-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

2 Installation

Packing List

You should have one distribution diskette containing the installation program and the compressed CTWALL program and data files. The installation procedure will uncompress the files onto a directory of your choosing. The following files will be installed:

X0153.EXE	The main executable program.
X0153.PDT	The printer definition table used to support the output of graphics to a printer.
COURB.FON	The screen font used in the program for graphical text output.
X0153D*.DAT	The example files. A total of 15.
X0153D*.OUT	CTWALL output of the example problems.
X0153.DOC	A file giving additional information about CTWALL.
X0153D.DOC	The file describing any discrepancies in the results from CTWALL compared with EM 1110-2-2502 and ETL 1110-2-322.

Equipment and Software Requirements

To use the CTWALL program, you will need the following ***minimum*** requirements:

a. **An IBM AT computer or compatible**. You will need at least 1.4 Mb of disk space to store the CTWALL program and accompanying files.

b. **420 Kb Memory**. CTWALL requires 420 Kb of conventional random access memory (RAM) to run. The installation procedure will preform a memory check and alert you if there is insufficient memory to run the program. You can also use the DOS CHKDSK command or the MEM command in DOS 4.0 or 5.0 to report the

amount of conventional memory available. If you do not have enough RAM, alter your CONFIG.SYS and/or AUTOEXEC.BAT files to remove miscellaneous device drivers, remove Terminate and Stay Resident (TSR) programs, decrease your FILES or BUFFERS statements, etc., until you have freed up enough memory.

c. **Monochrome or color monitor.** The program supports both monochrome and color monitors. CTWALL also supports the use of CGA, EGA, and VGA graphic adapters.

d. **Epson, LaserJet, and other printers.** The program supports the output of graphics (screen dumps) to a variety of printers. The command to send graphics to the printer is available from pull-down menus when viewing the graphical output.

Installation Procedure

To install the program, perform the following steps:

a. Insert the distribution diskette into a disk drive (e.g, drive A or B).

b. Log onto drive A or B (e.g., type **A: <CR>**).[1]

c. Type **INSTALL <CR>**.

d. Follow the questions.

The installation program will allow you to install the CTWALL program in a directory of your choosing. The installation program will also tell you if your machine does not have sufficient memory available to run CTWALL.

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1 Text in bold indicates what the user is to type. Text located between < > indicates a key or sequence of keys to be pressed (e.g., **<CR>** denotes a carraiage return, **<ALT X>** denotes holding down the ALT key and pressing the X).

3 Overview of Program Operation

General

The program is designed to be highly interactive through the use of pop-up menus, scrollable lists, and pop-up data forms. The program is designed so that the designer can quickly and easily cycle through the stability analyses. The user can change the structural geometry between runs to zero in on a wall configuration that satisfies the analysis criteria and is also economical. Graphics are available to view the input as well as the output. The input data and results of the analyses can be viewed by using a scrollable list or can be sent to a printer or file.

Operational Modes

The program has two modes of operation, interactive and batch. The interactive version makes use of graphical menus and displays. The batch version simply reads in data from a file and writes out the results to a file.

Interactive mode

To begin execution of the interactive version of the program, do the following:

a. Change to the directory where CTWALL was installed (if you just finished installing, the installation program puts you in the directory automatically).

b. At the DOS prompt, type :

X0153 <CR>

Batch mode

To begin execution of the batch version of the program, do the following:

a. Change to the directory where CTWALL is located.

b. At the DOS prompt, type:

X0153 InputFile OutputFile <CR>

where **InputFile** is the data file to be read and **OutputFile** is the file where you want the results written. CTWALL will not prompt you if the output file already exists. CTWALL will simply overwrite the file.

Help System

At any time the user may receive help by pressing the **<F1>** key. The main help screen is shown in Figure 1. The figure describes the functions of the available key sequences.

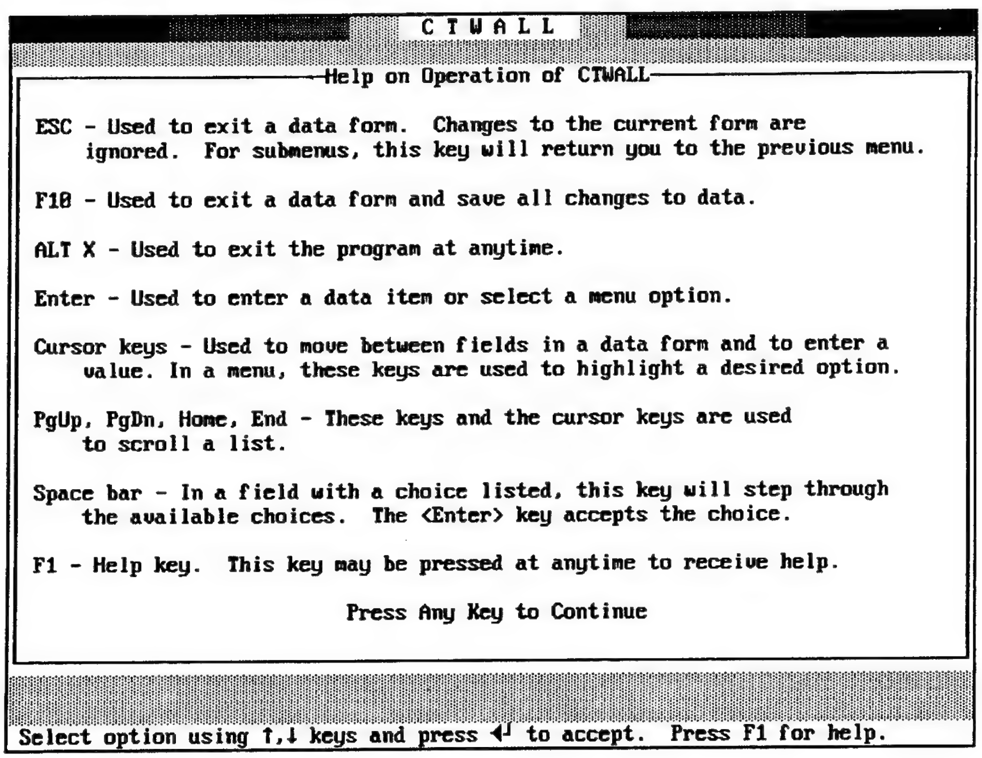


Figure 1. Main help screen

Sequence of Operation

This section describes, in general, the sequence of operations involved in running an analysis using CTWALL. The operations described in this section are more fully explained in Chapter 4, Interactive Operation of Program and Chapter 7, Input Guide.

Reading in data

There are two methods of entering data into the program. The user can enter data from a predefined data file or use an interactive data entry format. Even if data is entered using a data file, the user can still edit the data using the interactive format.

Verifying data

The data may be reviewed for correctness by viewing the input echoprint of the data. This echoprint is displayed in a scrollable window that can be scrolled forward or backwards through the printout. The user can also view a plot of the data to visually check that the data entered is what was intended.

Required data

There are several sections of required data that must always be entered. These required sections are the:

a. **Structural geometry**. The user enters dimensions of various parts of the structure such as the stem, toe, heel, and key. There are two different structural geometry screens that may be used. The user can choose the one which is easiest for the problem at hand.

b. **Soil geometry and properties**. The soil geometry on the driving and resisting sides of the structure are entered. The properties of these layers and the soil below the structure are also input.

c. **Water information**. The user can enter the water levels and the unit weight of water. Also, the method of computing uplift pressures on the base of the structure may be selected. The user can select the "line of creep" method or input pressures along the base of the structure.

d. **Required stability criteria**. The required factor of safety (FS) against a sliding failure and the percent of base in compression for the overturning analysis can be specified. These values are compared with computed values to report the adequateness of the analyses.

Optional data

There are several sections of optional data that are available to the user. These sections of data pertain to:

a. **Project information and title**. The user can specify project information such as a name, location, purpose, and designer. Also, a general-purpose five-line title can be input. Both the project information and general title appear on the output.

b. **Unit weight of the structure**. The unit weight of the structure is entered and used when computing the force due to the weight of the structure.

c. **Vertical surcharge**. The user can enter both vertical uniform and strip surcharges.

d. **Horizontal surcharge loads**. Both horizontal pressure and line surcharges can be entered.

e. **Analysis options**. The user may alter assumptions used in both the sliding and overturning analyses. Options such as the percent of passive force assumed in the overturning analysis, the failure angle of the wedges, the existence of water-filled cracks, and the existence of a crack to the bottom of the base of the structure are available. Some options affect just the sliding or the overturning, or both the sliding and overturning.

Execution of analyses

After all input and options have been selected, the user selects the execute command from the input options menu and the analyses are performed. At completion of the analyses, an abbreviated output giving the factor of safety against sliding and the percent of the base in compression is presented. A report is also made verifying if the stability is satisfied as compared to the required criteria entered. If the stability is not satisfied, the user has the option of altering the structural geometry and rerunning the analyses as described in the following sections.

Output options

Several options are available to the user upon completion of the stability analyses. These options are:

a. **Change structural geometry**. The user can select to change the structural geometry to try and satisfy the stability requirements. The structural geometry screen will be displayed for the user to make changes after which the analyses are immediately rerun. The user then has the option to change the structural geometry again if

stability is not satisfied and repeat the procedure. This loop is a quick way to alter geometry, rerun, review the abbreviated output, and rerun until stability is achieved. Once the required stability criteria are met, the user may review the more extensive full output.

b. **Edit other data**. The structural geometry, soil geometry and properties, and the stability criteria can be edited. The difference between this and the above option is that the stability analyses are not automatically rerun.

c. **View the results**. This option can be used to view the full output at the terminal, send the results to a file, or print the results on a connected printer.

d. **Plot the results**. Both a failure surface plot and a free-body diagram can be displayed to help interpret the results.

e. **Restart**. The user may reset the program to default conditions and return to the initial main menu to analyze another problem.

Saving Your Work

To save the current data into a file for future use, the user simply selects the "File Save" option when available. This option is available before and after analyses are run.

Stopping the Program

There are several places where the option to exit the program exists. Once selected, the user is queried as to whether this is what he really wants to do. Also, the program can be stopped from within any menu by holding down the **<ALT>** key and pressing **X**. This **< ALT X>** sequence will also query the user for confirmation.

4 Interactive Operation of Program

Main Menu

After beginning program execution, a main menu is displayed as shown in Figure 2. The options available and their associated functions are listed below:

a. **Terminal input**. This option allows the user to enter information about the structural geometry, soil geometry and properties, water data, and FS data through the use of interactive screens.

b. **File input**. This option allows the user to enter data by reading in a predefined data file.

c. **Edit file**. This option allows the user to edit or create a data file for subsequent runs. The editor is discussed in more detail in Appendix C.

d. **View file**. This option allows the user to view a file in a scrollable window to verify its contents.

e. **Utility equations**. This option allows the user to use interactive equation solvers for equations contained in EM 1110-2-2502 and ETL 1110-2-322. The utility equations are discussed in more detail in Appendix D.

f. **Setup**. This option allows the user to set preferences for certain aspects of the program, such as graphics mode, printer type, graphics output quality and orientation, and the size of the left margin for printouts. The setup procedure is explained in detail in Appendix B.

g. **Information**. This option allows the user to view information about the development of the program and how to obtain technical assistance. The user may also view a short questionnaire about the program.

h. **Quit**. This option allows the user to exit the program and return to DOS.

Each of these options will be discussed in more detail in the following sections.

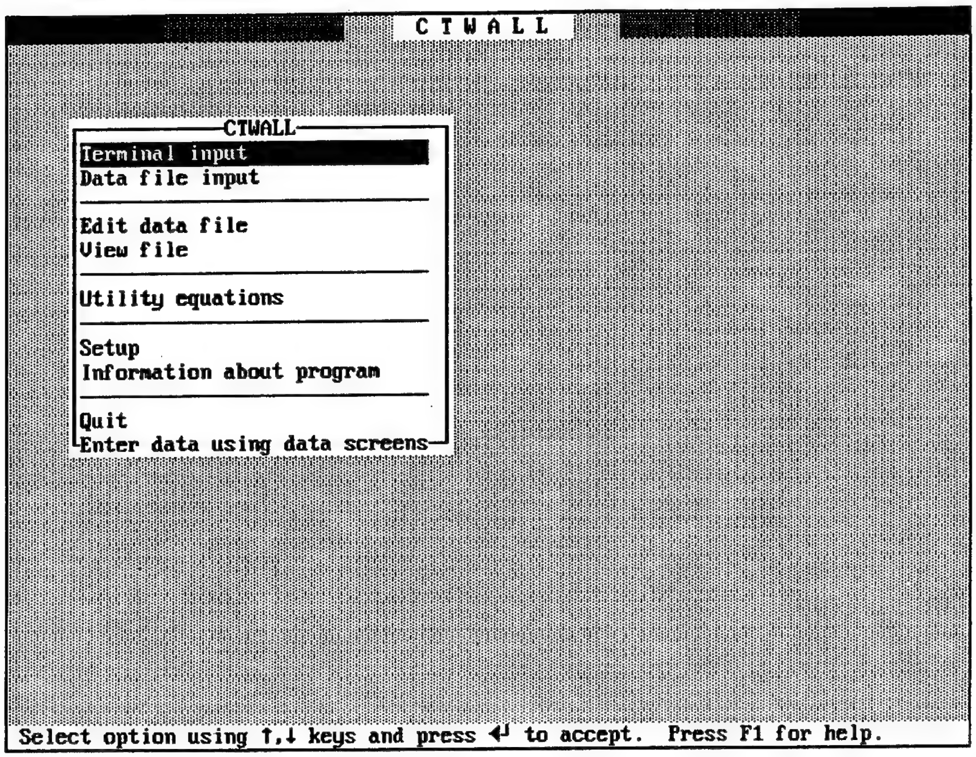


Figure 2. Main menu

Choosing Terminal or File Input

The user is allowed to enter data from the terminal using menus or by using a predefined data file. Any input data, no matter how it is entered, can also be saved into a file for future use. At the start of the program, the user is given the choice of terminal or file input as shown in Figure 3.

Use the up and down arrow keys to highlight the desired choice and press the **<Enter>** key. If terminal input is requested, the program will progress through several menus for the user to enter required data. If file input is requested, the user should enter a data file name which the program will read.

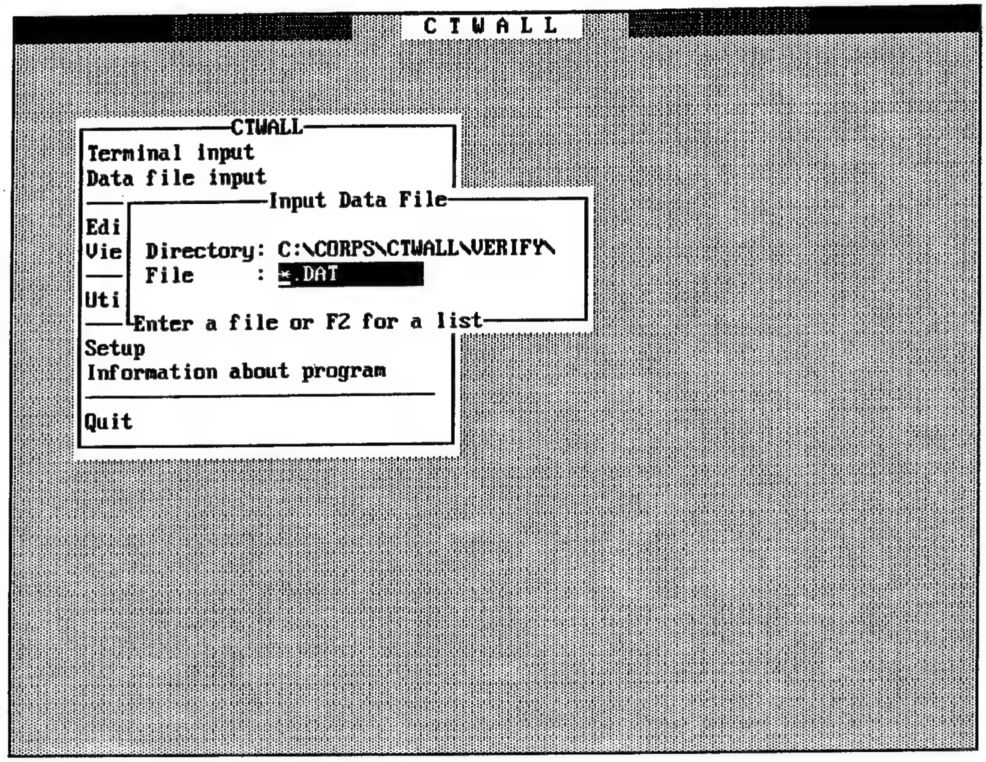


Figure 3. Input data file selection

Required Data Input

A sequence of four to five screens are progressed through when inputting data from the terminal. Information must be entered concerning the structural geometry, soil geometry, soil properties, and water data. To enter data in these screens, the user simply types in a number and presses the **<Enter>** key or the **<up>** or **<down>** arrows. The user can go forward or backward through the data by using the **<up>** and **<down>** arrow keys as much as desired. Input for a screen is complete when the **<Enter>** key is pressed in the last field of the data form or the **<F10>** key is pressed.

Structural geometry screen

There are two different structural geometry data entry screens that can be used. The screen shown in Figure 4 is the default screen labeled as structural screen 1. The screen shown in Figure 5 allows a more complex geometry and is labeled as structural screen 2. The user can make structural screen 2 the default by following the setup procedure described under the section entitled Setup Procedure. Depending on the problem, one screen may offer data entry advantages over the other.

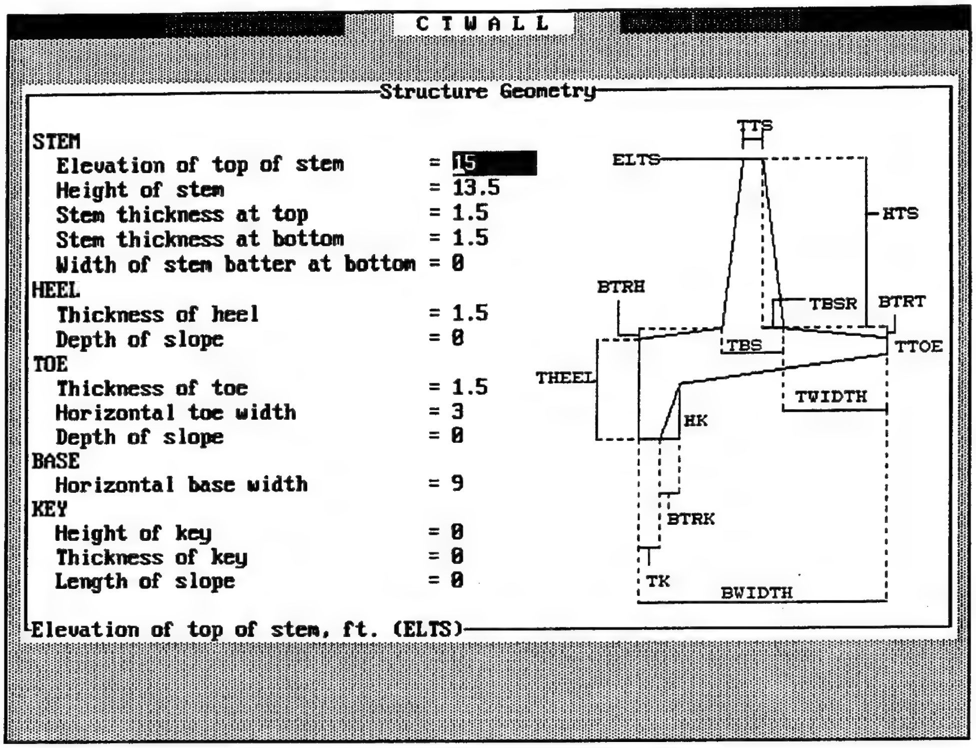


Figure 4. Structural geometry screen 1

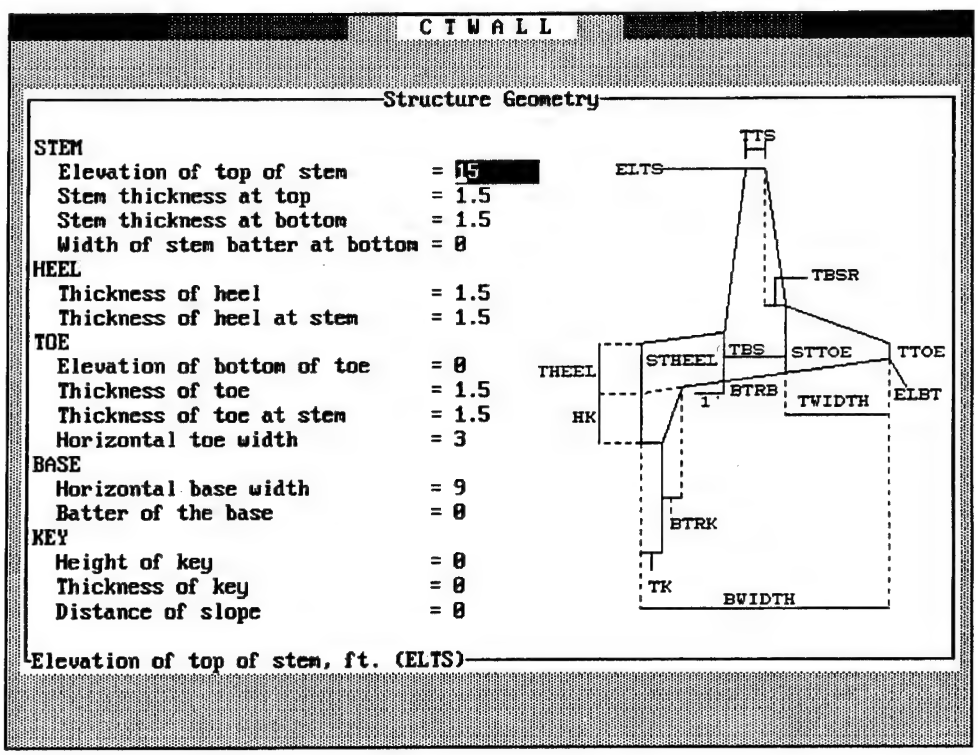


Figure 5. Structural geometry screen 2

Soil geometry screen

The soil geometry screen consists of the geometry of the driving side and the resisting side soil as shown in Figure 6.

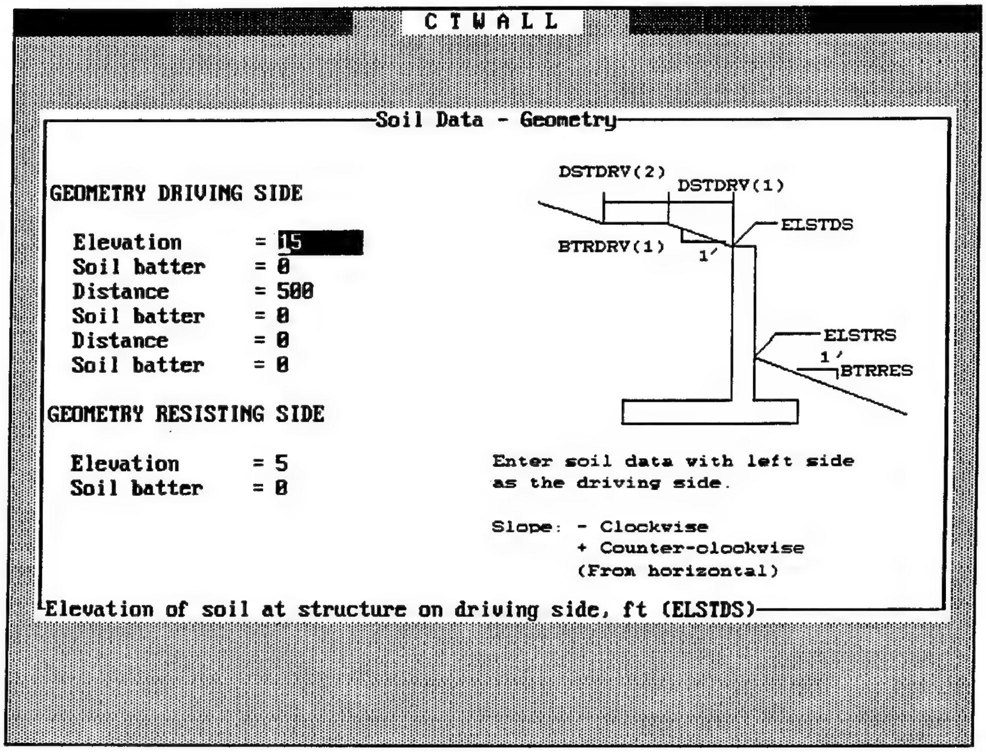


Figure 6. Soil geometry screen

Soil properties screen

The properties of the driving side soil, resisting side soil, and the soil beneath the base of the structure are entered in the soil properties screen as shown in Figure 7.

Water data screen

The water levels, unit weight of water, and the method of computing seepage pressures are entered in the water data screen as shown in Figure 8. There is an optional screen available for the water data. In the last field of the screen, the **<space bar>** can be used to toggle between the methods by which seepage pressures are calculated. If the option of "Input Pressures" is chosen, then the screen shown in Figure 9 appears in which the user can enter a desired pressure distribution.

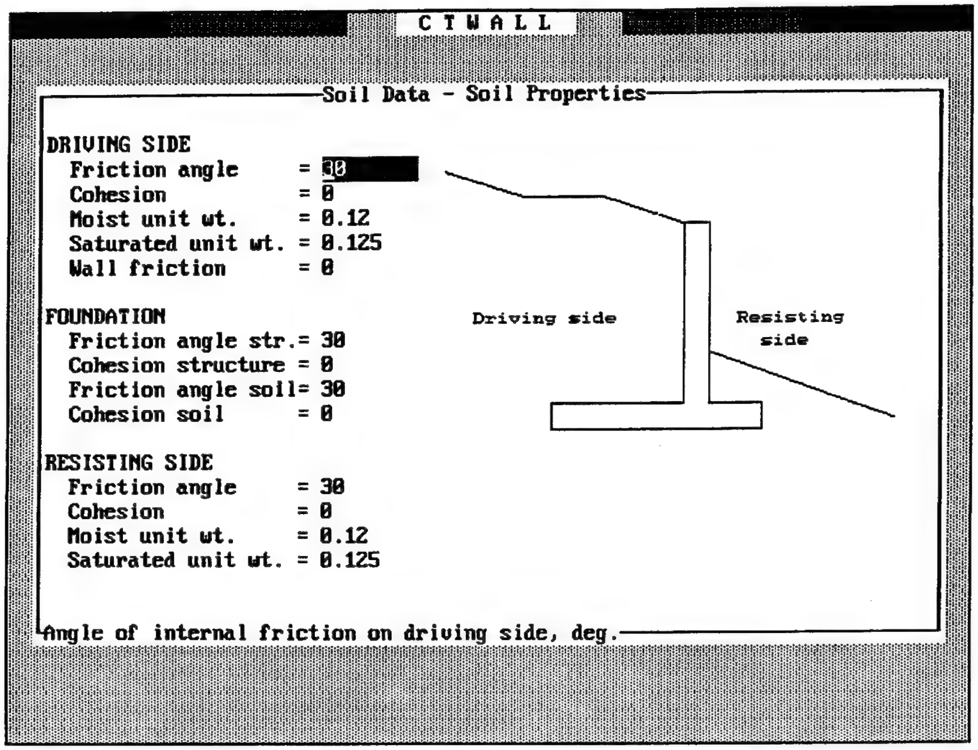


Figure 7. Soil properties screen

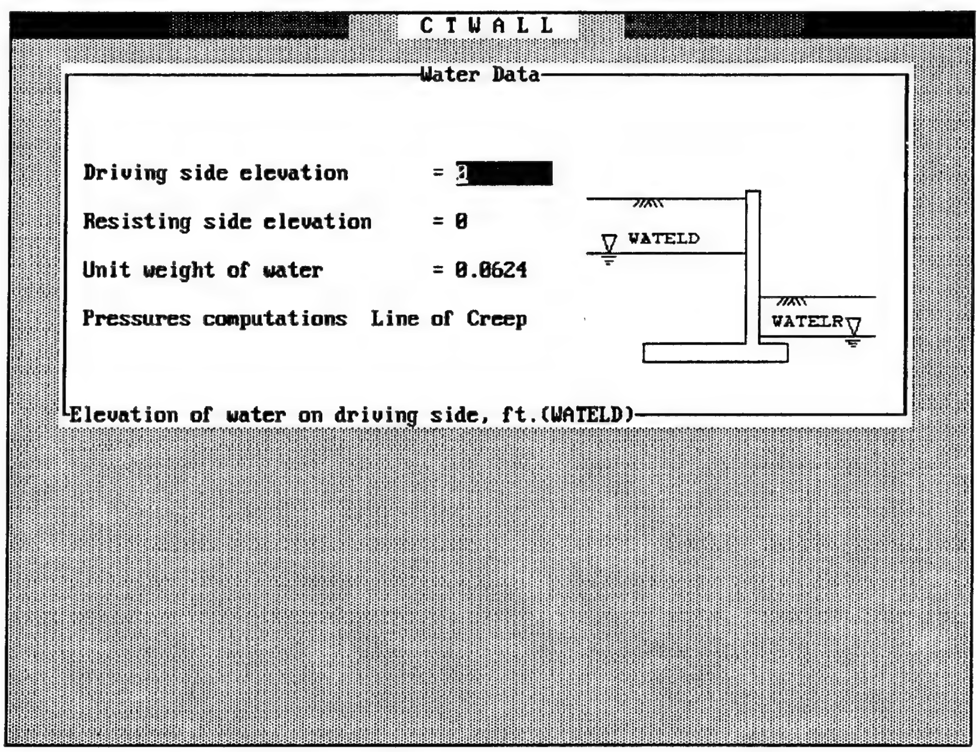


Figure 8. Water data screen

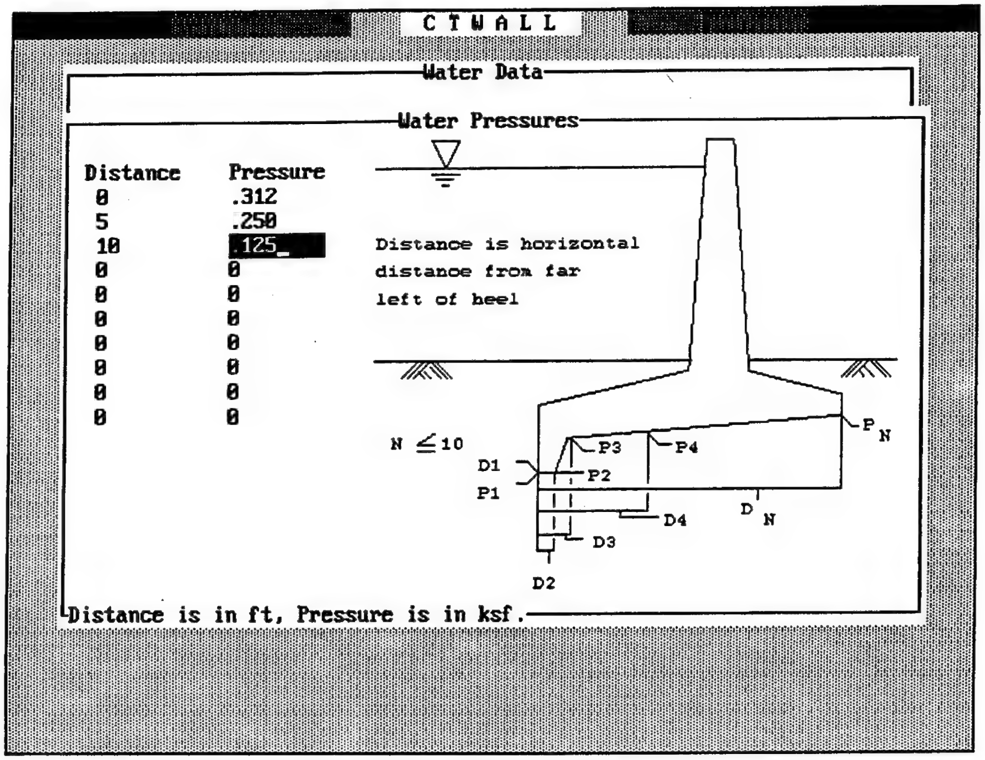


Figure 9. Input water pressures screen

Required stability criteria

The required factors of safety against a sliding failure and the percent of base in compression can be entered directly or from a table as shown in Figure 10. The table is from a table of load cases from Chapter 4 of EM 1110-2-2502. As mentioned previously, these criteria are compared to the computed values to report whether the stability criteria are satisfied.

Input Options Menu

After the required screens of data are entered, an input options menu as shown in Figure 11 is displayed. This menu allows several additional sections of data to be entered. These sections of data are discussed below.

Project data and general title

The user can enter information to identify the wall and program run as shown in Figures 12 and 13. This information is printed at the top of the input echoprint and with the results from the analyses.

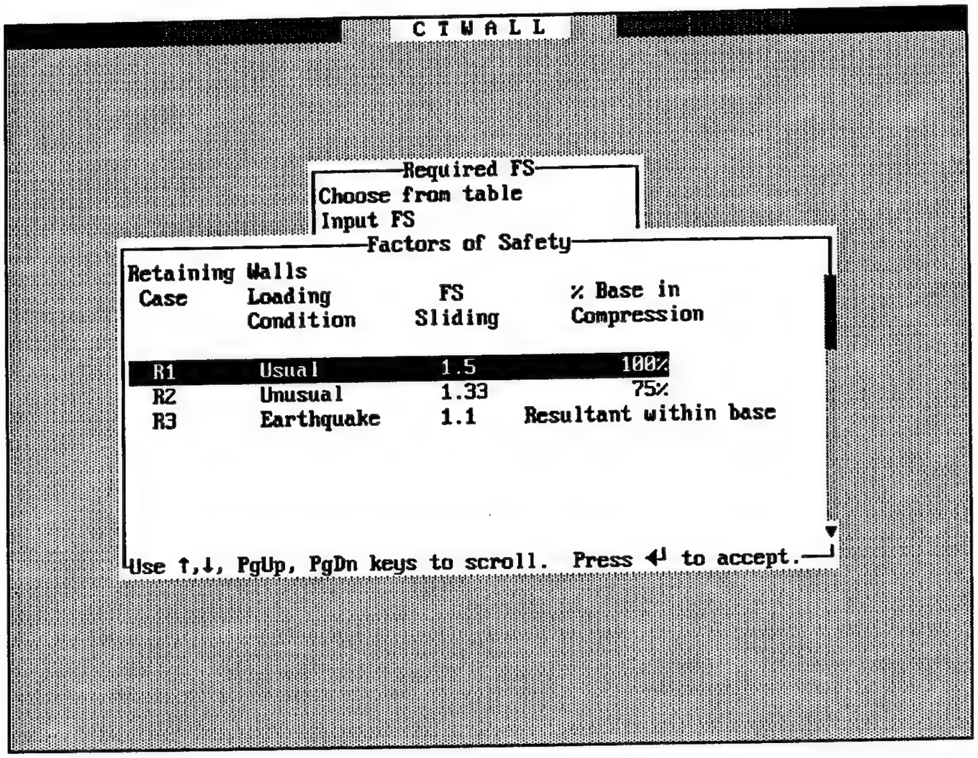


Figure 10. Required stability criteria input

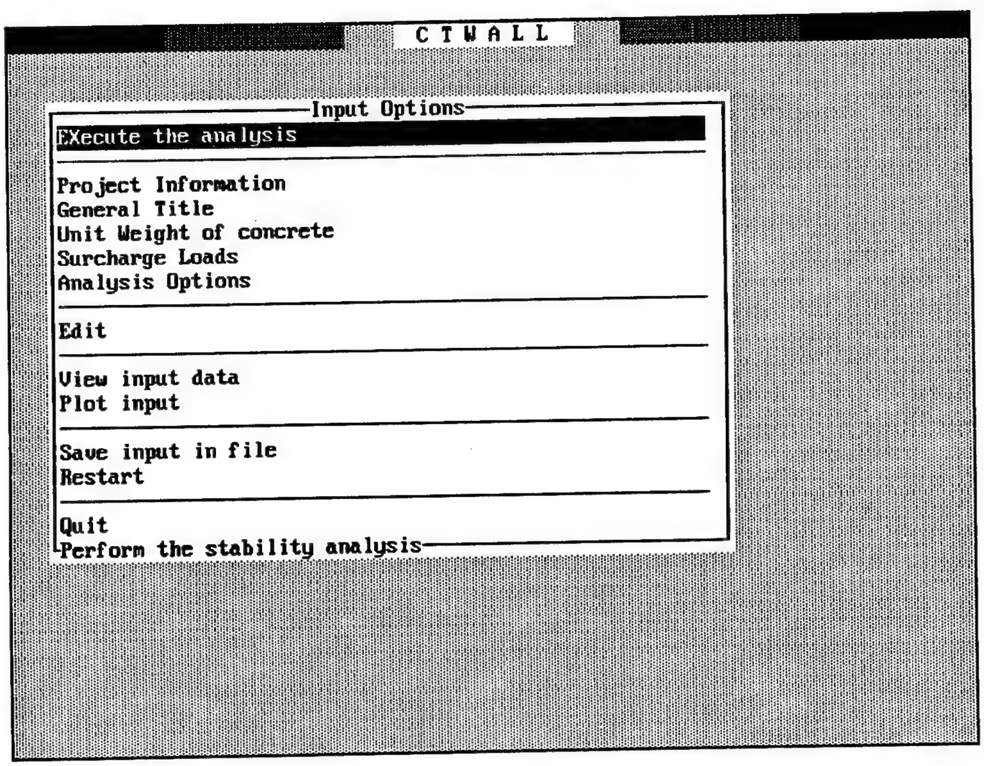


Figure 11. Input options menu

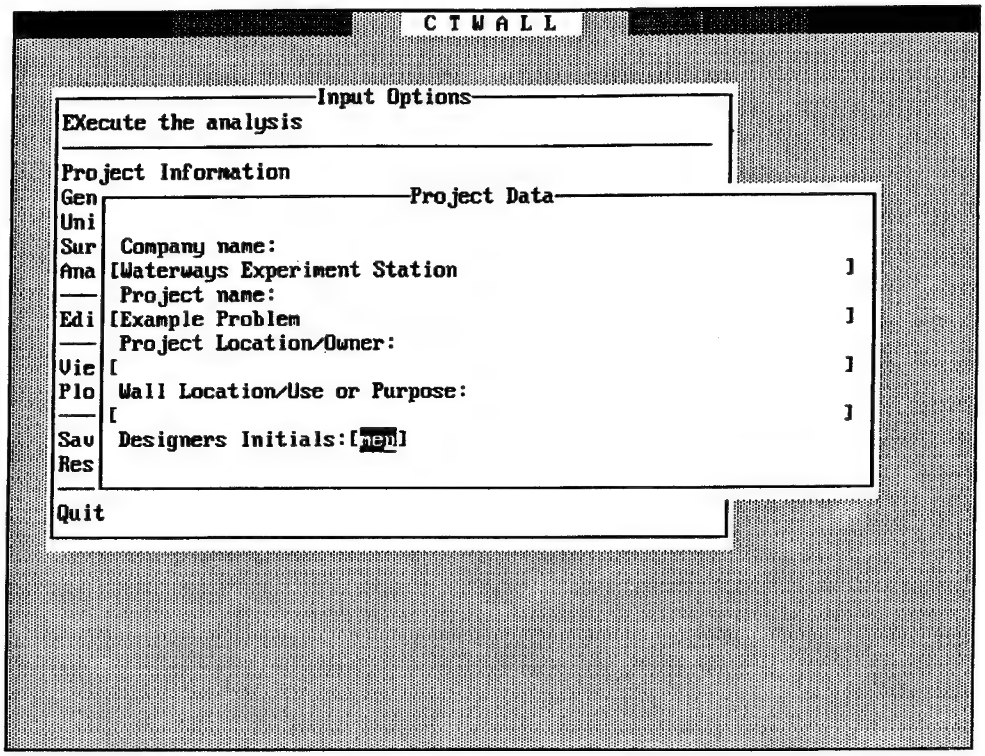


Figure 12. Project information screen

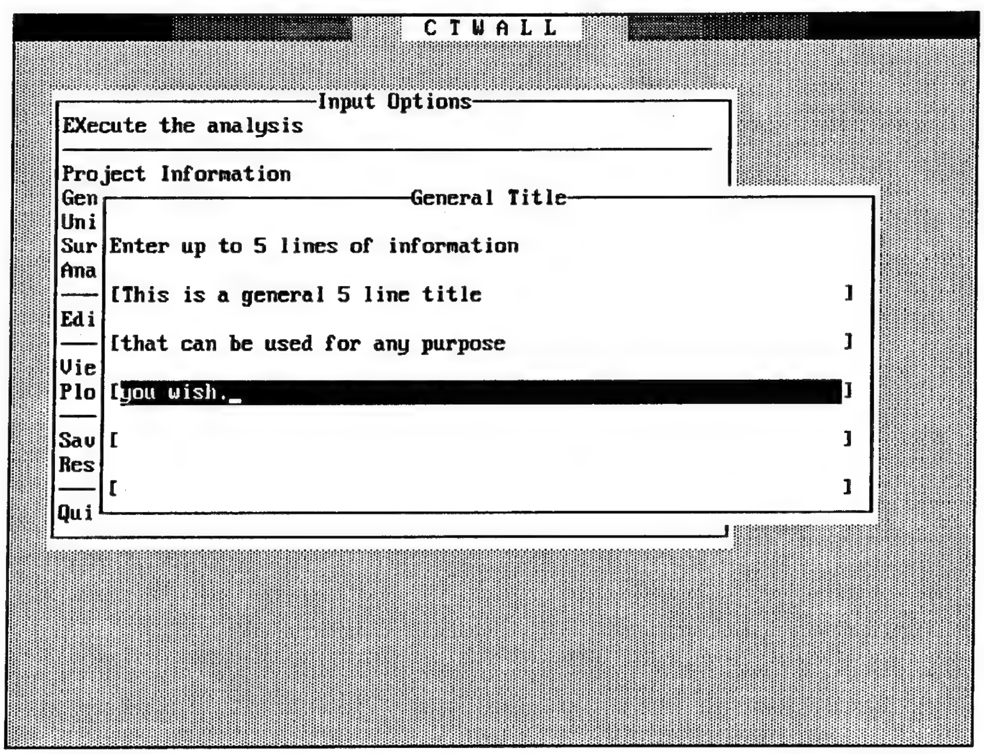


Figure 13. General title

Unit weight of concrete

The unit weight of the structure can be changed from the default of 0.15 kcf as shown in Figure 14.

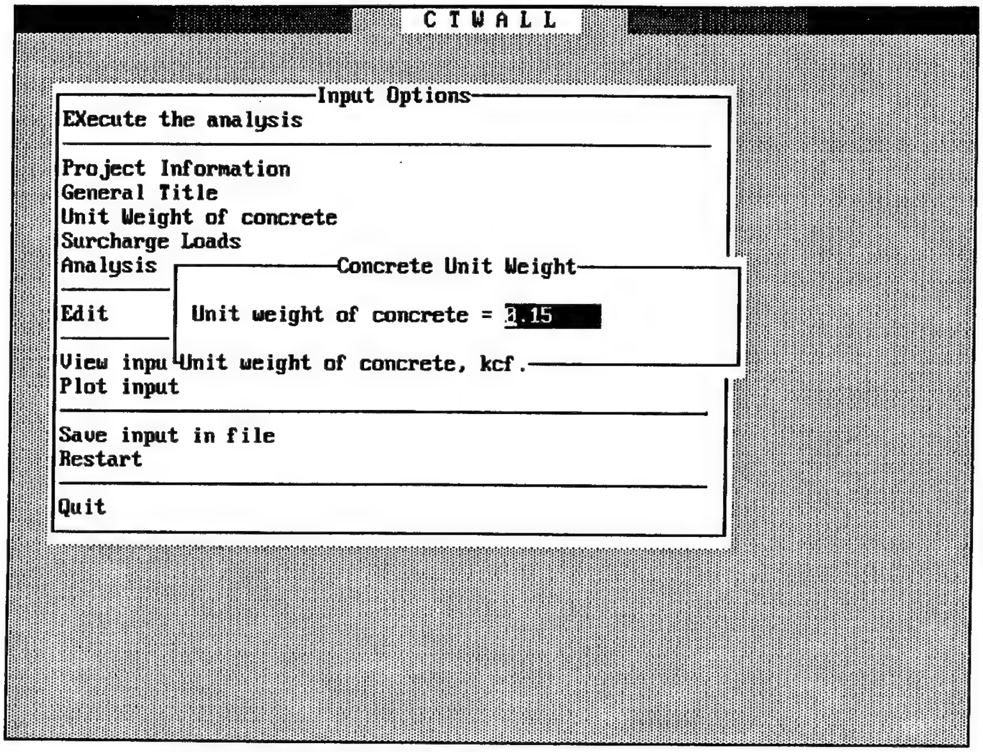


Figure 14. Unit weight of structure screen

Vertical surcharge loads

Two types of vertical surcharge loads, strip and uniform, can be entered as shown in Figures 15 and 16.

Horizontal surcharge loads

Two types of horizontal surcharge loads are available. Both horizontal line loads and pressure loads are available. These loads could be used to represent wave loadings, wind loadings, or other externally applied horizontal loadings. These loads are shown in Figures 17 and 18.

Analysis options

The default options used by CTWALL when performing the stability analyses can be altered in the "Analysis Options" screen shown in Figure 19. In this screen, options affecting the sliding, overturning, and sliding and

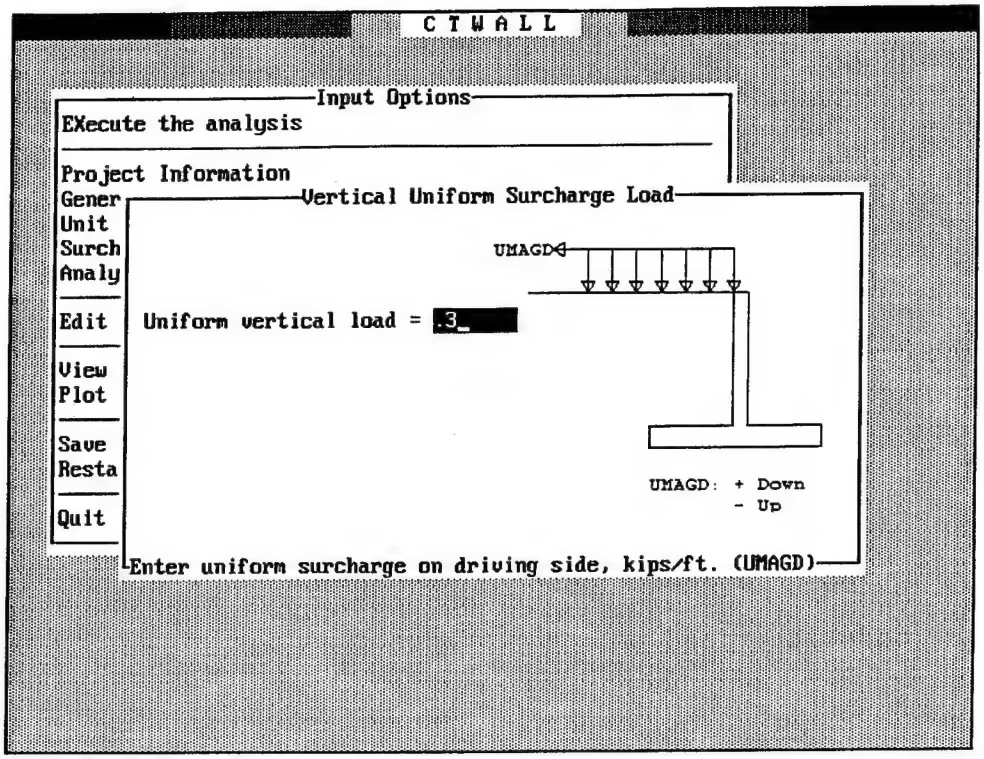


Figure 15. Uniform vertical surcharge screen

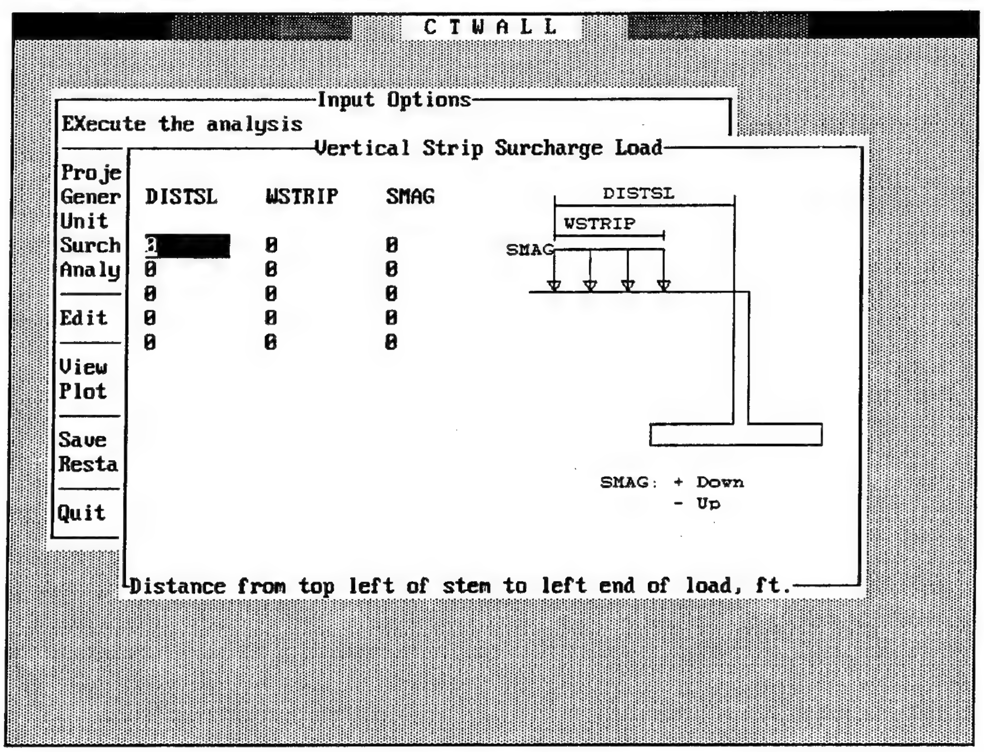


Figure 16. Vertical strip surcharge screen

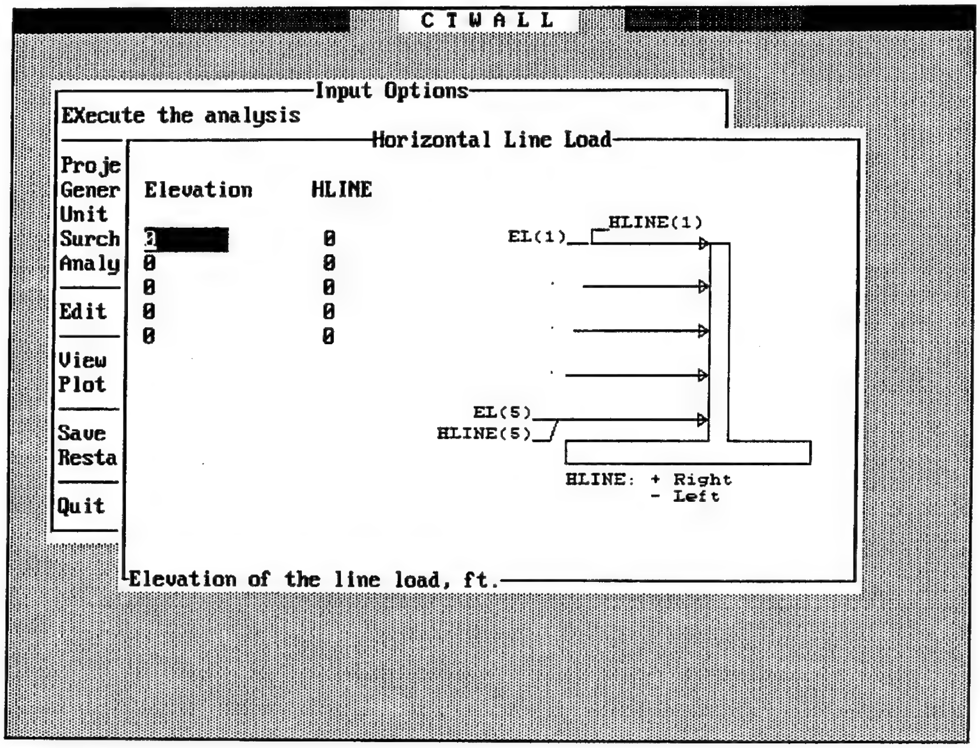


Figure 17. Horizontal line loads screen

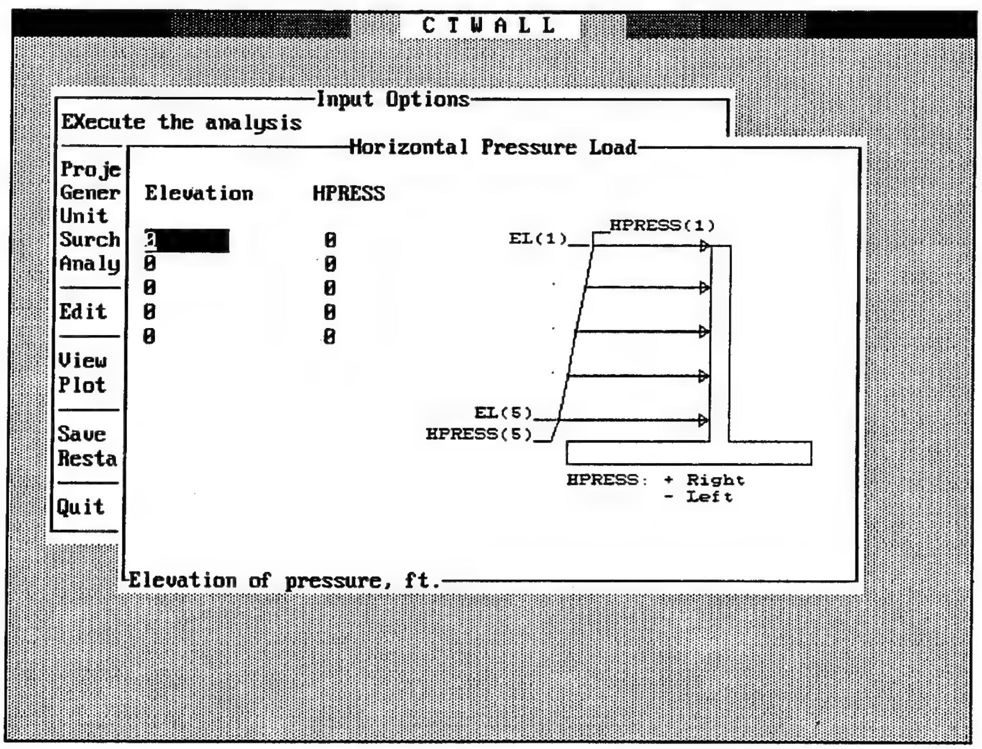


Figure 18. Horizontal pressure loads screen

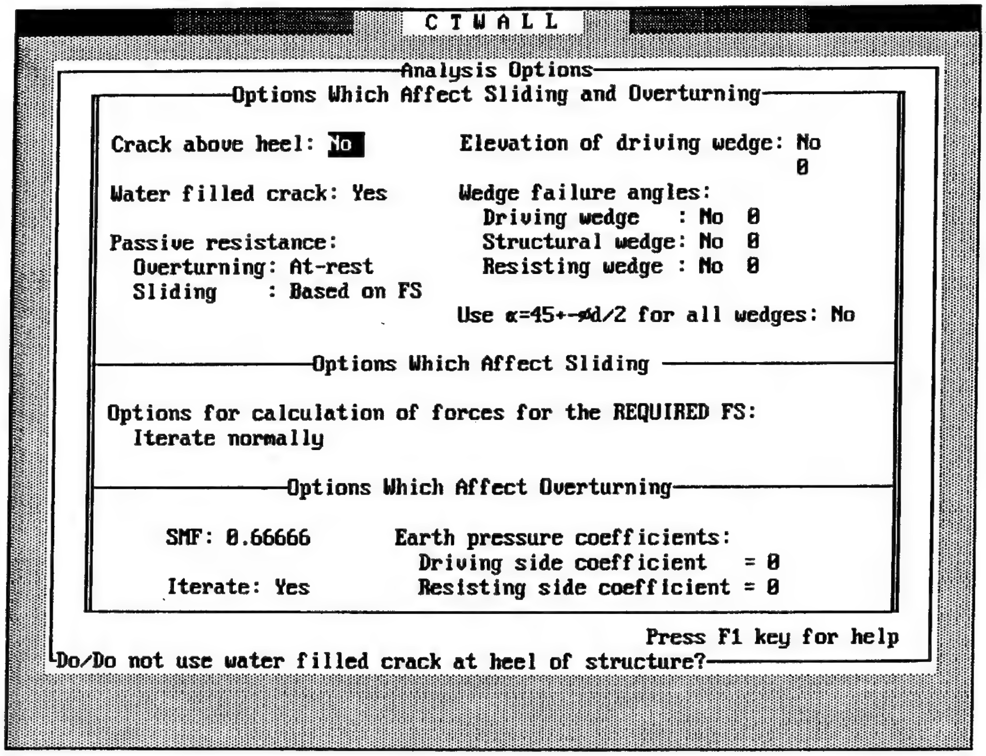


Figure 19. Analysis options screen

overturning can be set. Each of these options is discussed in more detail below:

a. **Crack above heel**. This option will force a crack down to the bottom of the heel. If the water level is above the crack, the crack will be filled with water. This option is intended to allow the examination of a floodwall.

b. **Water-filled crack**. This option will fill any computed cracks with water. The depth of cracking is based on the developed cohesion.

c. **Elevation of driving wedge**. The elevation of the starting point of the base of the driving wedge can be input. This option allows the modeling of an embedded structure in rock.

d. **Passive resistance**. The amount of passive resistance to use in the overturning and sliding analyses can be chosen. For overturning, percentages up to one-half full passive resistance may be chosen. For sliding, the resistance may be assumed to be zero or may be computed based on the FS.

e. **Wedge failure angles**. The failure angles of any of the wedges can be set. This will predetermine the failure path. This option is used in cases where the failure along a specific plane is known.

f. **$45 \pm \phi/2$ wedge angles**. This option will use the relation $45 \pm \phi/2$ to calculate the failure angles of the wedges.

g. **Calculation of forces for the required FS**. This option will allow the user to examine the forces for a particular FS or have the program calculate the force required to hold the system in equilibrium for a particular FS. This latter option is intended to allow the examination of walls restrained by an adjacent slab.

h. **SMF**. The user can select the strength mobilization factor (SMF) to be used in the overturning analysis. EM 1110-2-2502 specifies that an SMF = 2/3 is to be used in an overturning analysis. If an SMF = 1.0 is used, the full active and passive pressure forces will be used.

i. **Iterate in overturning**. If 100 percent of the base of the structure is not in compression, the program will iterate to find the actual percent of base in compression. This option will cancel this iteration procedure.

j. **Earth pressure coefficients**. The program will automatically calculate the earth pressure coefficients to use in the analyses. The user may input his own coefficients, if desired.

Editing input

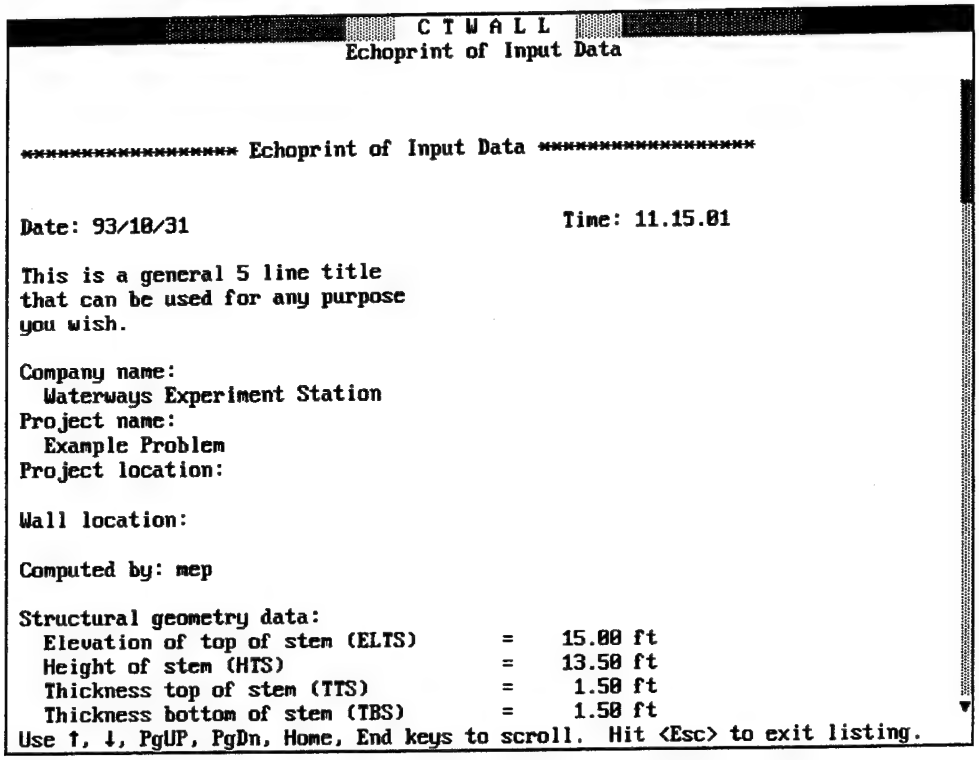
The user can return and edit any of the required information screens previously discussed. These are the structural geometry, soil geometry, soil properties, water data, and FS data screens. After a screen has been edited, the user is returned to the "Input options" menu where another screen can be chosen for editing.

Viewing input data

After data have been entered, either from a file or interactively, an echoprint of the data may be viewed. The echoprint will display the input data and specify any options which have been set. This will allow the user to verify the data that have been entered. The input is displayed in a scrollable window as shown in Figure 20.

Plotting input data

The input data may also be plotted to visually verify the entered data. An example of an input data plot is shown in Figure 21. Several options are available from a menu at the top of the plot. The user may add an axis and/or grid, window in on a particular part of the plot, or print the plot on an attached printer. The printer must be connected to LPT1.


C T W A L L
Echoprint of Input Data

****************** Echoprint of Input Data ******************

Date: 93/10/31 Time: 11.15.01

This is a general 5 line title
that can be used for any purpose
you wish.

Company name:
Waterways Experiment Station
Project name:
Example Problem
Project location:

Wall location:

Computed by: mep

Structural geometry data:

Elevation of top of stem (ELTS)	=	15.00 ft
Height of stem (HTS)	=	13.50 ft
Thickness top of stem (TTS)	=	1.50 ft
Thickness bottom of stem (TBS)	=	1.50 ft

Use ↑, ↓, PgUP, PgDn, Home, End keys to scroll. Hit <Esc> to exit listing.

Figure 20. Input echoprint of data

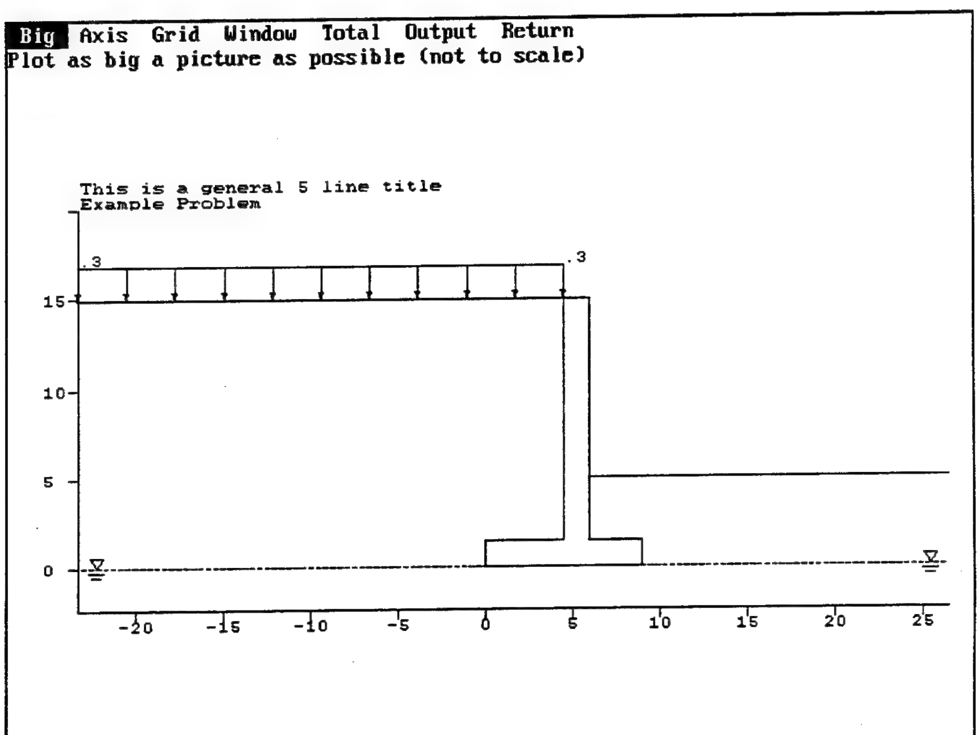


Figure 21. Input data plot

Saving data

The user may also save the current data into a file for future use by using the "Save input" option. A file name is requested to save the data into. If the file already exists, the user is given the chance to enter a new file name or overwrite the existing file.

Restarting program and exiting

The user may reset the program to the start-up defaults and begin a new problem by selecting "Restart." Selecting "Exit from program" will return the user to DOS.

Abbreviated Output Listing

After the analyses have been run, an abbreviated output is given which lists each analysis, whether the user's criteria were met, and some suggestions of things to try if the criteria were not met. The abbreviated output is shown in Figure 22.

```
                              C T W A L L
                           Abbreviated Output
***** Summary of Results *****

This is a general 5 line title

Project name: Example Problem

***************    *** Not Satisfied ***
* Overturning *    Required base in comp. = 100.00 %
***************    Actual base in comp.   =  76.26 %
                   Overturning ratio      =   1.72

  To increase stability try one or a combination
  of the following:
    1.  Increase the base width
    2.  Slope the base of the structure
    3.  Lower the wall base
    4.  Add/remove key

Xr (measured from toe) =   2.29 ft
Resultant ratio        =  .2542
Stem ratio             =  .3333
Base pressure at x=   6.86 ft from toe =     .0000 ksf
Base pressure at toe                   =    4.3603 ksf

***********    *** Satisfied ***
* Sliding *    Min. Required =   1.50
***********    Actual FS     =   1.55
Use ↑, ↓, PgUP, PgDn, Home, End keys to scroll.  Hit <Esc> to exit listing.
```

Figure 22. Abbreviated output

Output Options Menu

The output options menu shown in Figure 23 will allow the user to change the structural geometry and cycle back through the stability analyses, view the full output results, view output graphics of the failure surface or a free-body diagram of the structural wedge, or several other options as described in the following sections.

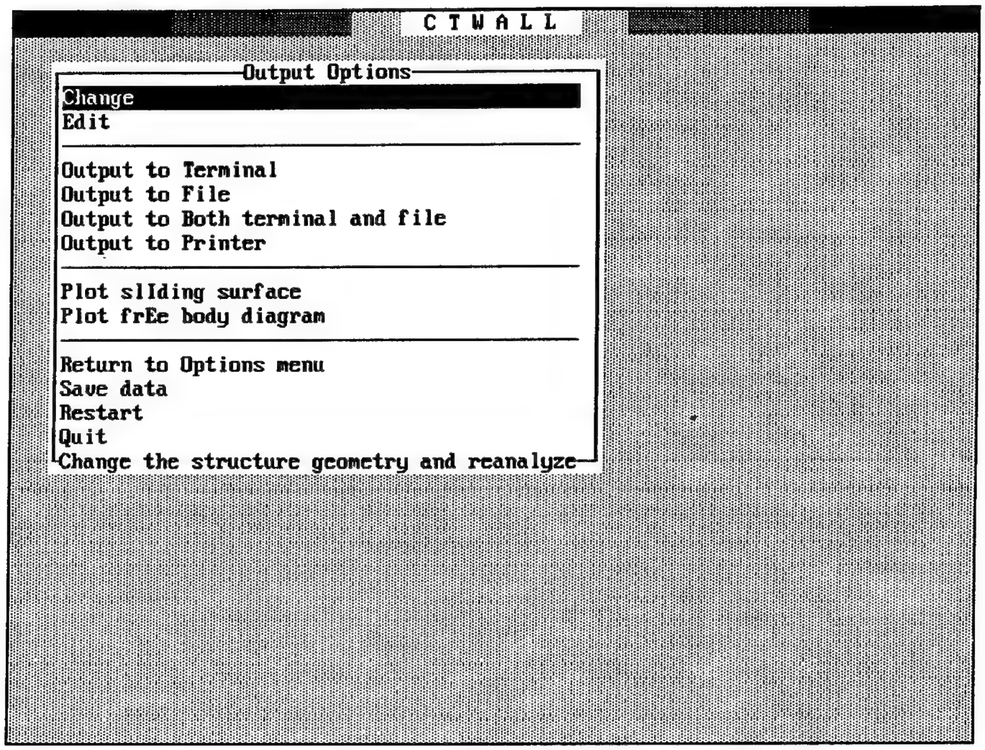


Figure 23. Output options menu

Changing structural geometry

This option will return the user to the structural geometry screen where the dimensions of the wall can be changed. When the user exits from the structural geometry screen, the analyses are automatically rerun. This provides a fast method to alter the structural geometry and rerun the analyses.

Editing required sections of data

If the user desires to change data other than the structural geometry, this option will allow the editing of any of the required sections on input data.

Viewing or printing output results

To view the output results or send the results to a printer or file, one of the print options can be selected. If results are sent to a printer, the printer must be connected to LPT1.

Plotting the output

The user can view both a failure surface plot and a free-body diagram plot. The failure surface plot displays the failure surface computed in the sliding analysis. The free-body diagram plot of the structural wedge displays the forces and pressures computed in the overturning analysis. These plots are shown in Figures 24 and 25.

Returning to input options menu

The user can select the "Return to input options menu" to modify any of the input data.

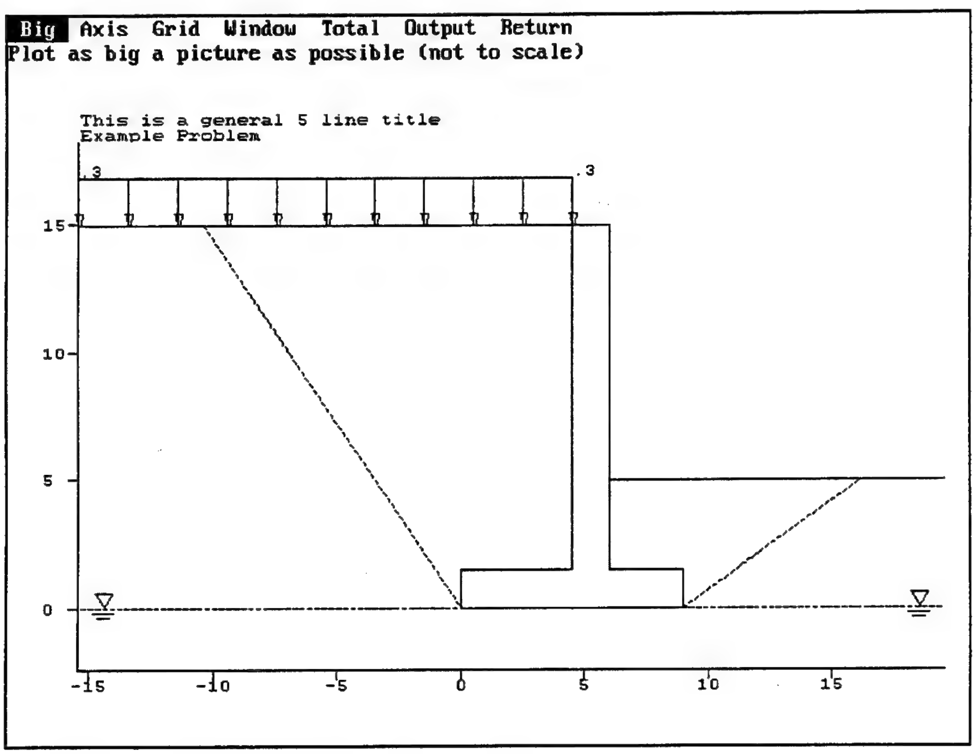


Figure 24. Failure surface plot from sliding analysis

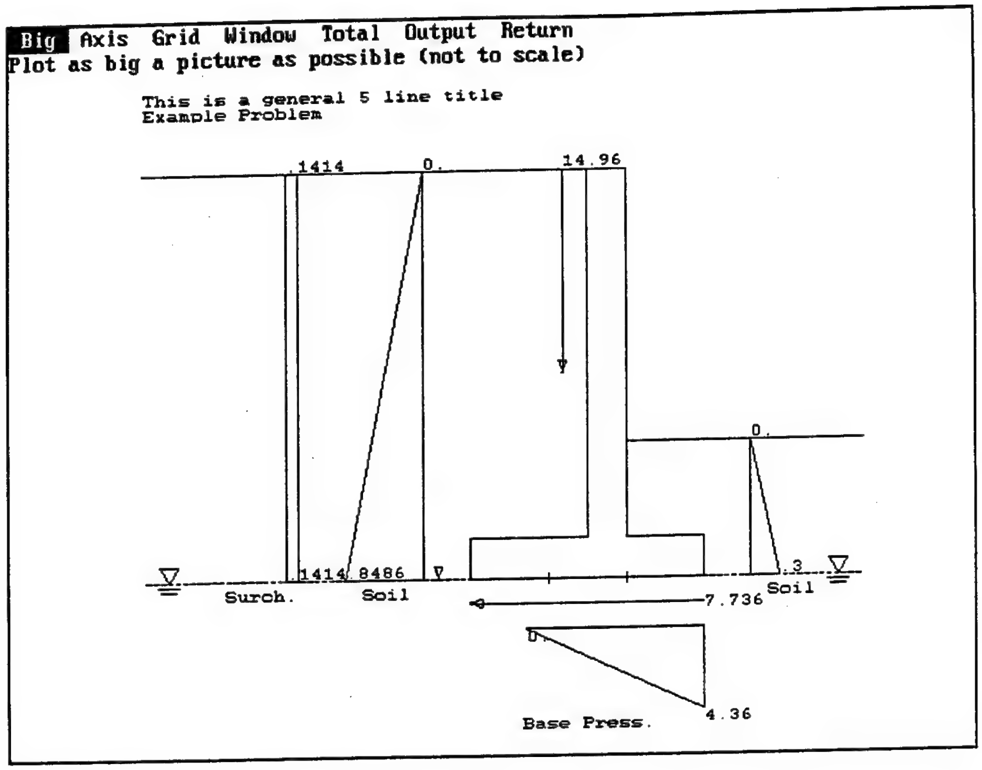


Figure 25. Free-body diagram from overturning analysis

5 Capabilities of Program

Structural Geometry

The structure can consist of a stem, toe, heel, and key. The base of the structure can be horizontal or sloped. Some various valid structural configurations are shown in Figure 26. Valid base configurations are shown in Figure 27. There are two options for entering the structural geometry as shown in Figures 4 and 5. The default option is shown in Figure 4. The user can use whichever method is easier for the geometry at hand. The setup screen accessed from the main menu is used to switch between the two methods of entry. The setup procedure is explained more fully in Appendix B.

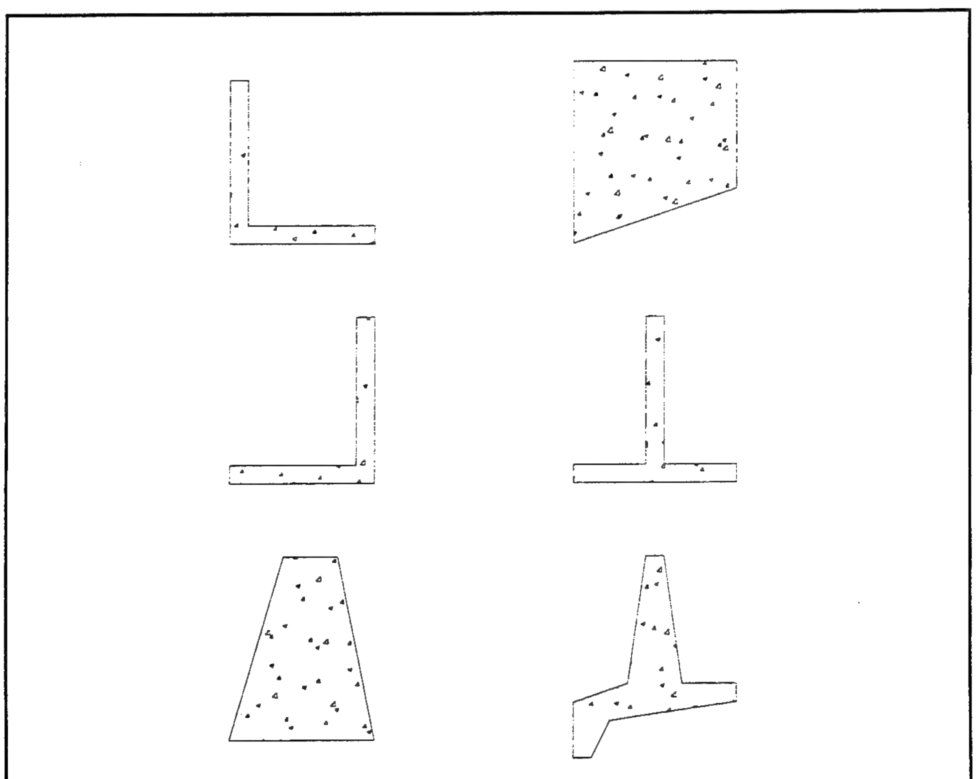


Figure 26. Examples of valid structural configurations

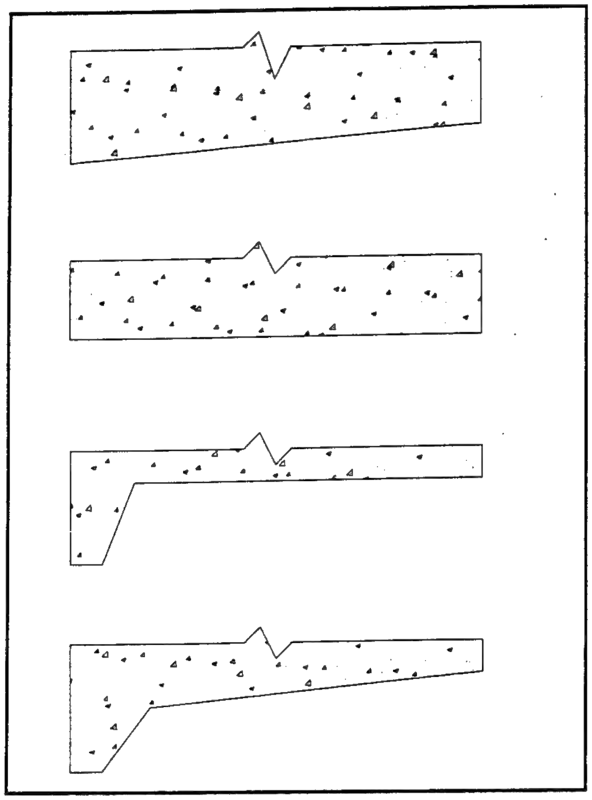


Figure 27. Valid base configurations

When a data file is read into the program, the method of entry of the structural geometry is controlled by the "STRUCTURE" command explained in Chapter 7. The program will automatically use whatever method is used in the data file, no matter what default option is currently selected.

Soil Layers

There can be one soil layer on the driving and resisting sides of the structure. The soil layer on the driving side can have up to three slopes. The resisting side must have a constant slope. Soil layers must intersect below the top of the structure and above the base of the structure. A "no wedge" condition can be modeled by inputting a soil layer elevation at the base of the structure. The soil geometry is shown in Figure 6.

Soil Properties

Both the driving and resisting sides can have an angle of internal friction ϕ and a cohesion value c. In addition, the driving side can have a wall friction value δ. The wall friction must always be positive. Also, the soil layers can possess both moist and saturated unit weights. The program will use the moist weight above the water level and the saturated weight below the water level. Buoyant weights are calculated using the saturated weight.

The foundation soil has two sets of soil properties consisting of a ϕ and a c. One set of properties is used for the soil-structure interface and the other set of properties is used for the soil-soil interface. The values used in the analyses depend on the interface being examined. For example, the user could examine a plane below the base of the structure for sliding. In this case, the properties of the soil-soil interface would be used.

Water Levels

A water level can be entered for each side of the structure. The driving side water level must be equal to or greater than the resisting side water level. The water levels can be above or below the structure. If the water levels are input at the same elevation, hydrostatic water pressures are computed. If there is a difference in water levels, seepage pressures are computed. The procedure used to calculate seepage pressures is explained in the following text.

Water Pressures

Water pressures are calculated using the following three procedures:

a. **Line of creep**. The line-of-creep procedure will linearly dissipate head along the shortest seepage path. The shortest seepage path is the wetted perimeter of the structure embedded in the soil.

b. **Hydrostatic pressures**. Hydrostatic pressures are computed as the vertical distance from the water level to a point multiplied by the unit weight of water. Hydrostatic is only used if the water levels input are equal.

c. **Input pressures**. Input pressures are user supplied pressures at points along the base of the structure. Input pressures can be used to simulate flow net results or to produce full head values along the base of a wall (for instance, if a wall is founded on rock). Up to 10 pressures can be entered along the base of the wall.

These methods of computing water pressures are explained in detail in Chapter 6, Analysis Procedures.

Vertical Surcharges

Two types of vertical surcharges are available: strip and uniform. A strip load has a finite width and extends infinitely in the direction perpendicular to the cross section. The uniform loading is a load that has an infinite width and extends infinitely in the direction perpendicular to the cross section. Both of these loadings are described in paragraph 3-16 of EM 1110-2-2502.

Up to five strip surcharges can be entered. Only one uniform load can be entered. The surcharges can only be located on the driving side of the structure. The surcharge loading are projected loadings (i.e., they are

based only on the horizontal distance loaded). Strip surcharge loadings can be superimposed to approximate other loadings, such as ramp loadings. Line loads can be modeled by a strip load of width equal to 1 ft.

Horizontal Surcharges

Two types of horizontal surcharges are available: line and pressure. The line and pressure surcharges extend infinitely in the direction perpendicular to the cross section. Up to five line loads may be entered. Up to five horizontal pressures may be entered to approximate a pressure distribution on the structure. The horizontal pressure loads are assumed to act on the structural wedge.

Computation of Cracks

There are two options for handling the formation of cracks on the driving side of the structure. They are:

a. **Full crack**. The user can force a crack down to the base of the structure on the driving side. This is intended to facilitate the modeling of floodwalls. If water is present, full hydrostatic pressure is applied in the crack. This option is used in both the overturning and sliding analyses.

b. **Water-filled crack**. The user can elect to fill computed cracks with water. If a soil possesses cohesion, a crack depth is automatically calculated for the soil layer based on the developed cohesion. The developed cohesion is based upon the SMF used in the overturning analysis or the FS used in the sliding analysis. If selected, this crack depth can be filled with water. If a crack is formed below the water level, it is filled with water automatically. Since any cracks formed may become inundated, this option simplifies the modeling of water-filled cracks.

Driving Wedge Elevation

The elevation of the driving wedge may be input if desired. This option is intended to allow the modeling of a wedge which does not begin at the base of the wall (e.g., if the wall is founded in rock). This option affects both the overturning and sliding analyses. Figure 28 shows the effect of using the driving wedge elevation option.

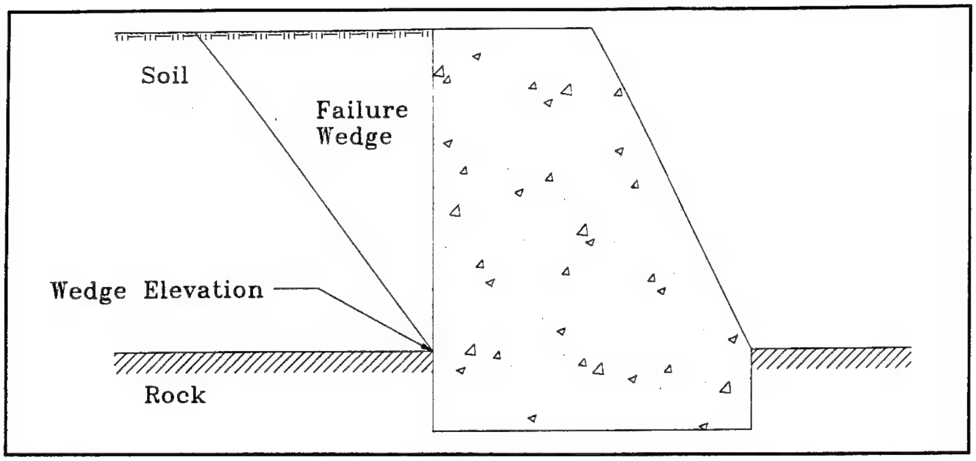


Figure 28. Wedge elevation option

Passive Resistance

The magnitude of the earth pressure forces on the resisting side can be controlled for both the overturning and sliding analyses. For the overturning analysis, the magnitude of the passive resistance can be chosen to approximate at-rest conditions or can be selected as a percentage of full passive resistance ranging between 0 and 50 percent. The passive resistance for the sliding analysis can be set to 0 or computed based on the FS. Setting the passive resistance to 0 is essentially forcing the existence of a "no wedge" condition on the resisting side of the structure.

Failure Angles of Wedges

There are three wedge angle options available to the user. They are:

a. **Automatic calculation**. The user can let the program automatically iterate for the critical wedge angles. The critical angles are the ones that produce a maximum driving force and a minimum resisting force.

b. **Set the failure angles**. The user can specify a failure angle for any of the wedges. This is useful if parts of a failure path are predefined, and it also aids in searching below the base of the structure for a critical sliding plane.

c. $\boldsymbol{\alpha = 45 \pm \phi_d/2}$. This option will compute the failure angles of the wedges based on the equation $45 \pm \phi_d/2$ for the driving and resisting wedges. The developed angle of internal friction ϕ_d is based on the SMF used in the overturning analysis and on the assumed FS used in the sliding analysis. Any failure angles which are "set" by the option described in *b* are not affected by this option.

Forces in Sliding Analysis

There are three options available for the calculation of forces in the sliding analysis. These options are:

a. **Normal iteration.** This option will vary the FS assumed in the sliding analysis until the forces calculated satisfy equilibrium. The magnitude of the forces used in the analysis is subject to other options which affect the earth pressure forces computed for the driving and resisting wedges.

b. **Forces for the required FS**. This option will compute the forces for a specified FS. The FS used is the required factor of safety as described in the "Required Data Input" section in Chapter 4. This option is intended to allow the examination of forces for a particular FS of interest. It is important to note that for an arbitrary FS, the forces calculated will probably not result in equilibrium of the system.

c. **Forces required for equilibrium**. This option will calculate the resisting force required to hold the wall in equilibrium for the required FS. This option is intended to allow the examination of walls restrained by an adjacent slab. Therefore, the sliding analysis will report a resistance value sufficient to hold the wall in equilibrium for a specified FS. The resistance value can then be used to design the slab.

Strength Mobilization Factor

The SMF affects the amount of the shear strength of the soil that is mobilized or used in the overturning analysis. The SMF is more fully explained in paragraph 3-11 of EM 1110-2-2502. Two values of the SMF are worth noting. An SMF = 2/3 applied to the driving side soil properties will result in near at-rest earth pressure forces. An SMF = 1 will result in full active earth pressure forces. The default value for the SMF = 2/3.

Percent of Base in Compression

In the overturning analysis, if 100 percent of the base of the structure is not in compression and water pressures are present, an iterative procedure is used to calculate the actual percent of the base of the structure in compression. This procedure is more fully explained in the Chapter 6, Analysis Procedures.

Earth Pressure Coefficients

The user is allowed to enter earth pressure coefficients for the driving and resisting side soils. These earth pressure coefficients are used in the overturning analysis to compute earth pressure forces.

6 Analysis Procedures

General

The program has been designed to follow the criteria described in EM 1110-2-2502 and ETL 1110-2-322. The following discussion will not elaborate on the theory behind the analysis procedures but more on their implementation in the program.

Overturning

The overturning criteria used in CTWALL is described in Chapter 4 of EM 1110-2-2502. The procedure used in CTWALL is shown in the flowchart in Figure 29.

Outline of procedure

The program will calculate a percentage of the base of the structure which is in compression and report the location of the resultant of all forces applied to the structural wedge. The program will iterate, if necessary, to find the percent of the base in compression. This iteration will only occur if three conditions are met: (1) there must be seepage pressures present on the base of the structure, (2) the base of the structure must not have a key, and (3) less than 100 percent of the base of the structure must be in compression. If the base is not fully in compression, this means that part of the base is in tension. Tension between the base of the structure and the foundation is not allowed and the tensile pressures are neglected. The base is assumed to crack and full hydrostatic water pressures are applied to the part of the base of the structure which is not in compression (Figure 30). The overturning analysis is recomputed and the resulting percent of base in compression is compared to the previous iteration. If the resultants from the two iterations compare closely (to within

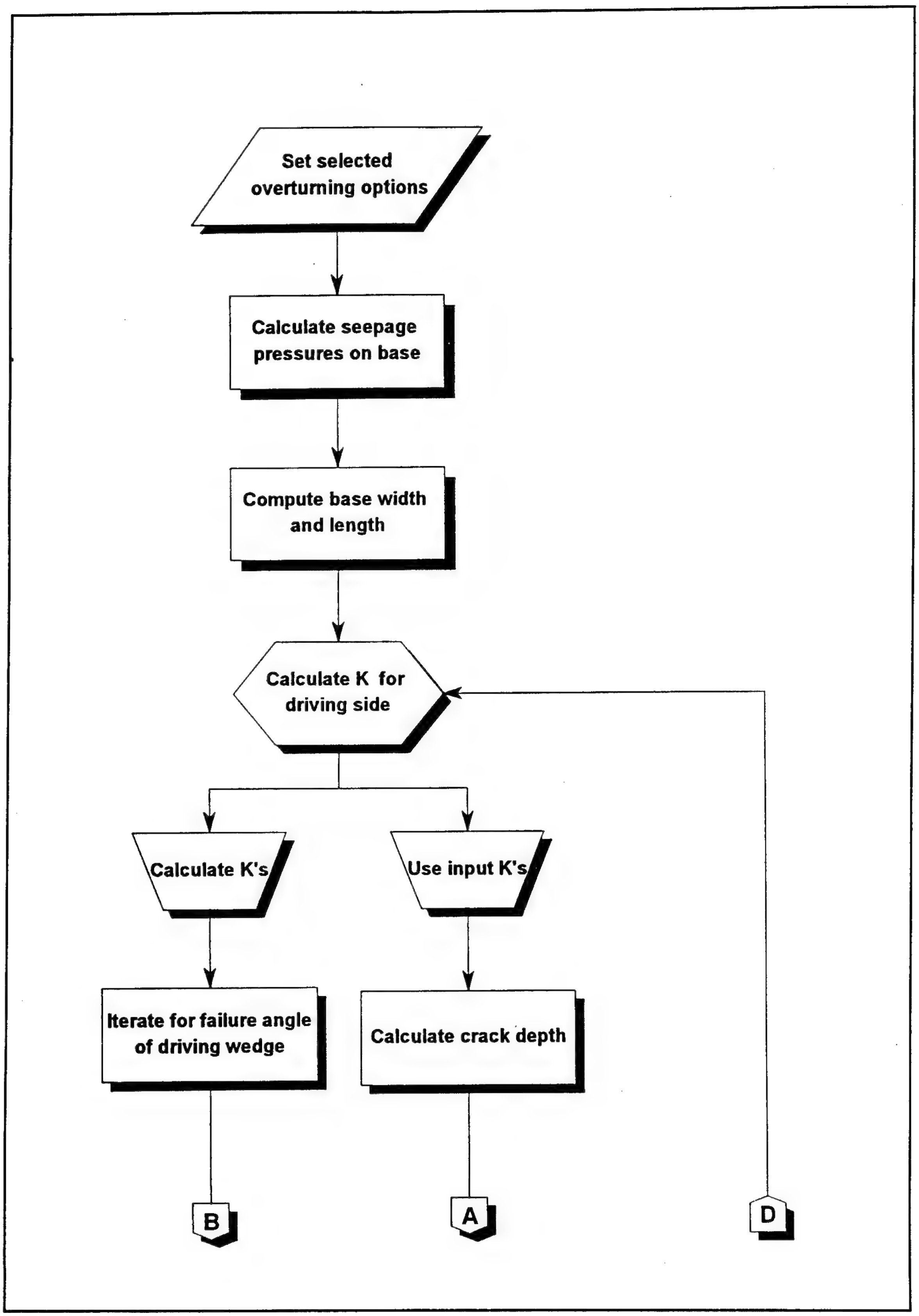


Figure 29. Flowchart of overturning analysis (Sheet 1 of 3)

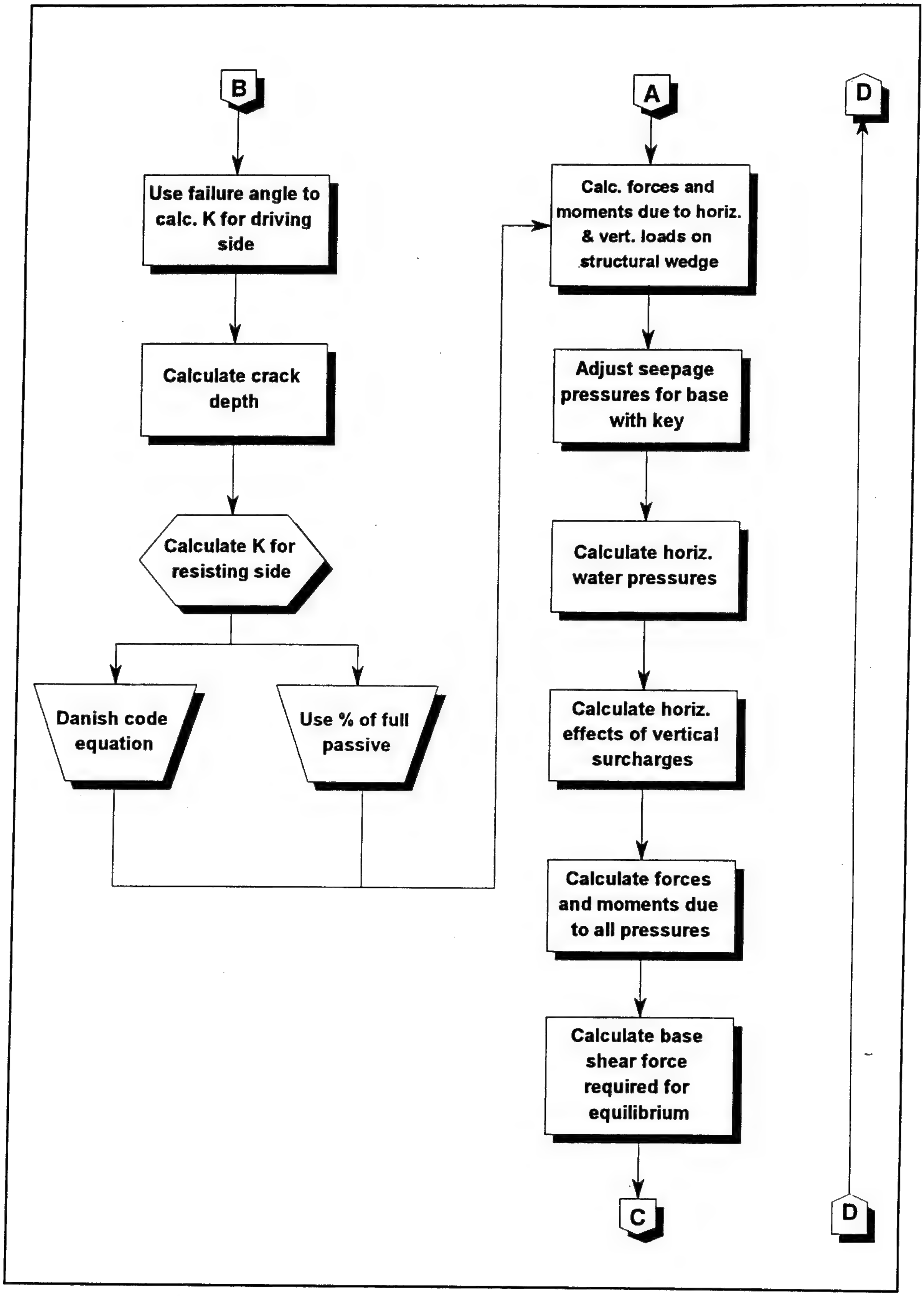


Figure 29. (Sheet 2 of 3)

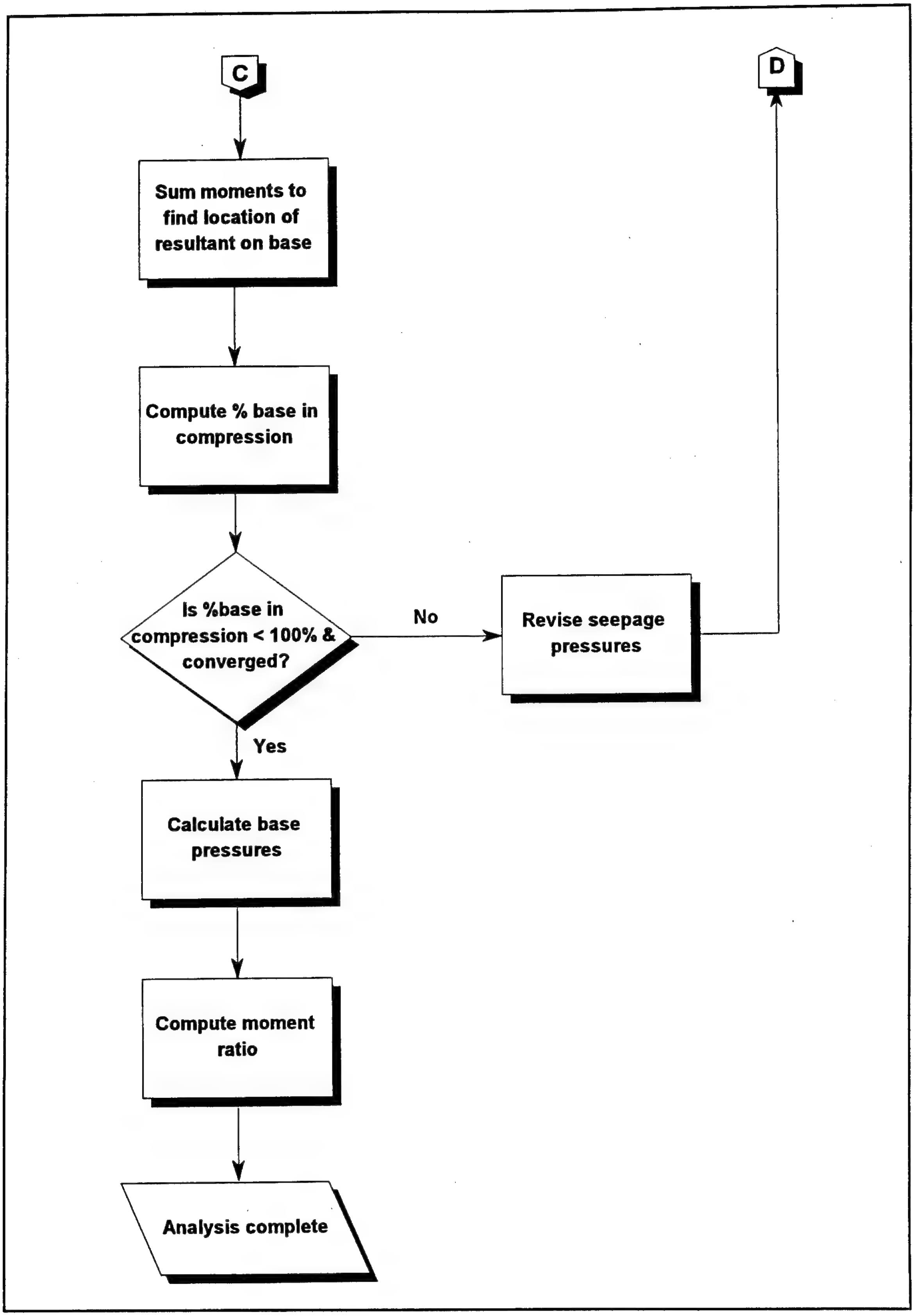


Figure 29. (Sheet 3 of 3)

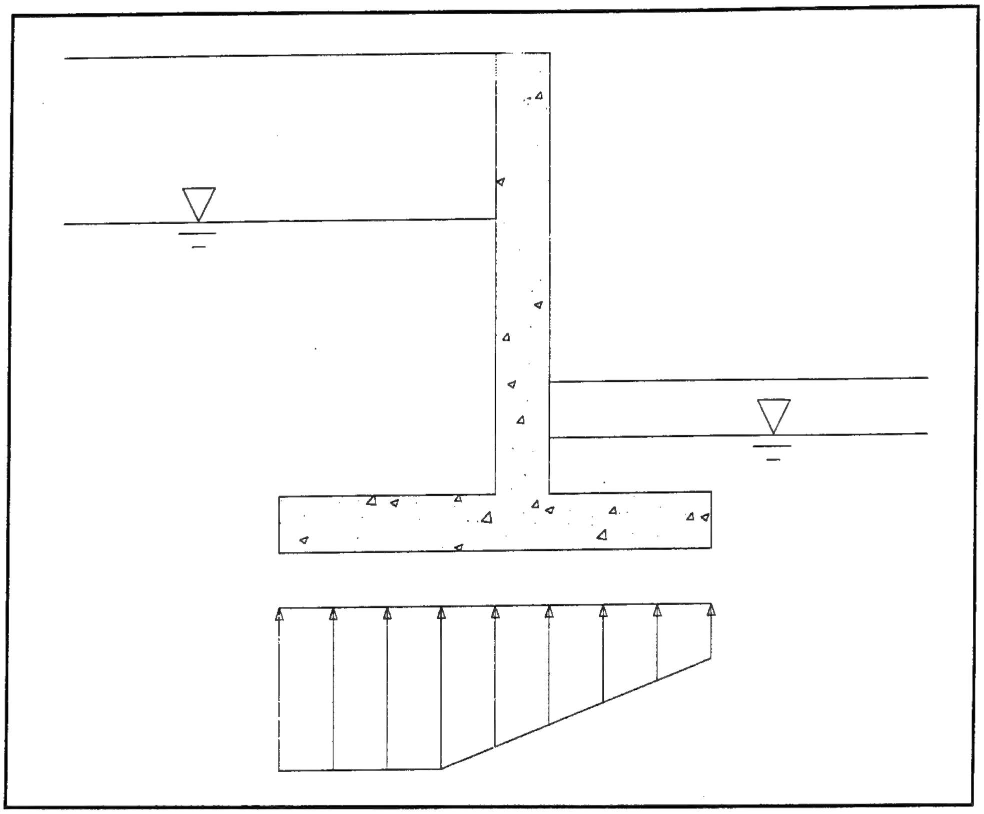


Figure 30. Full hydrostatic pressures across cracked portion of base

0.001 ft), the process is complete. Otherwise, full hydrostatic water pressures are applied over the new percent of the base which is not in compression, and the analysis is recomputed. For a base with a key, EM 1110-2-2502 states (paragraph 4-8d) that the soil will remain in compression contact with the structure. Therefore, there will be no crack formed for this case.

Seepage computations

During the overturning analysis, as CTWALL iterates to find the actual percent of the base of the structure which is in compression, the seepage pressures are continually updated. The pressures are updated because as the crack length along the base of the structure propagates, the seepage path is shortened. A new hydraulic gradient is computed and is used to compute new seepage pressures along the base of the structure. These seepage pressures, in turn, affect the critical failure angle of the driving wedge. The critical failure angle is computed as the one which produces the maximum driving force for a specified SMF. The critical failure angle also influences the calculated earth pressure coefficients and crack depth for the driving side.

This discussion assumes that the line of creep is being used for the computation of seepage pressures. The line of creep assumes that the head

loss is linearly distributed around the wetted perimeter of the embedded part of the base of the structure. This is shown pictorially in Figure 31. The distance used to calculate the hydraulic gradient is length ABCD.

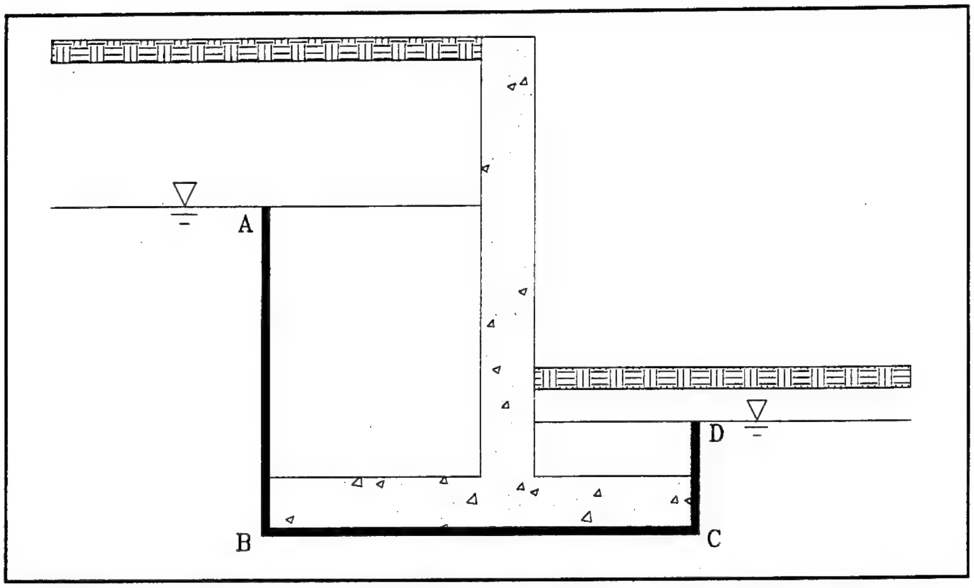


Figure 31. Line of creep method for seepage pressures

If input pressures are being used, the pressure input at the heel of the structure is applied across the cracked portion of the base of the structure. The remainder of the input pressure distribution remains unchanged.

The actual base of the structure is used in the overturning analysis. This means that a sloped base and key are taken into account. The seepage pressure distribution on the base is calculated at points along the base of the structure, not the sliding plane.

If the crack option at the heel is used, a crack is assumed down to the bottom of the heel, and the seepage path is adjusted accordingly.

Calculation of *K*'s

CTWALL will automatically calculate the value of the earth pressure coefficients for the driving and resisting sides of the structure. The procedure for the driving and resisting side soils are discussed below:

a. **Driving side**. The critical failure angle for the driving wedge is sought by an iterative procedure. This procedure yields the wedge angle giving the maximum driving force for the specified SMF (an SMF = 2/3 approximates at-rest conditions). This wedge angle is

then used to compute the value of the driving side earth pressure coefficient K_d.

b. **Resisting side.** The resisting side earth pressure coefficient K_r can be computed by two different methods. If the user selects at-rest pressures on the resisting side, the Danish Code equation is used to calculate K_r. If a percentage of the full passive earth pressure is desired, the full passive earth pressure coefficient is computed from Coulomb's equation using an SMF = 1. An SMF = 1 causes the full angle of internal friction of the soil to be used in computing the earth pressure coefficient. Full passive earth pressures are then calculated and scaled down to the specified percentage.

The *K* values referred to are used to develop earth pressure distributions. The equations used to calculate the *K* values and the method used to determine the earth pressure distributions are described in Chapter 3 of EM 1110-2-2502 and in ETL 1110-2-322.

If the user inputs values for the earth pressure coefficients, then the above procedure is bypassed and the input *K* values are used instead to develop the earth pressure distributions. The K_c value for cohesive materials for input *K*'s is calculated as the square root of the input *K* values for the driving and resisting sides (this really only applies to a horizontal ground surface). For computed *K* values, the K_c value is calculated from equations in EM 1110-2-2502 which apply to sloping ground surfaces.

K values for the driving side soil are based on the critical failure angle of the driving wedge as discussed above. The critical failure angle is affected by many factors such as surcharge loadings, soil properties, water pressures, soil geometry, and depth of cracking. One feature of this program is that cracks are automatically calculated for cohesive materials and the cracks are filled with water. The depth of cracking is dependent on the SMF assumed and on the critical failure angle. This, in turn, affects the *K* values calculated.

If the slope of the backfill (β) becomes too great (approximately 60 percent of ϕ), the suggested value of the SMF = 2/3 should be adjusted. Guidance on this is provided in ETL 1110-2-322.

Earth pressure calculations

Any negative soil pressures resulting from cohesion are set equal to zero in the overturning analysis. This essentially means that starting at the crack depth the effective earth pressure distribution is 0.

Exceedance of maximum base shear

The overturning analysis makes a check to determine if the maximum available shear force that can be developed along the base of the structure is exceeded. The analysis computes a shear force that is required to hold the system in equilibrium. This shear force is determined strictly from equilibrium. Therefore, this shear force may or may not be able to exist. The maximum available shear force is calculated using the unfactored shear strength properties of the soil. This maximum shear force is then compared to the calculated shear force required for equilibrium. If the maximum is not exceeded, the analysis is correct. On the other hand, if the maximum is exceeded, the shear force required for equilibrium cannot actually exist. In this case, a warning message is printed in the output alerting the user of this condition. The user should then try to increase the stability of the wall.

In certain cases, the overturning analysis may predict that the maximum base shear has been exceeded, but the sliding analysis will produce an FS greater than 1. The user could become further confused by checking the sliding analysis by the quick check described in Chapter 4, EM 1110-2-2502, only to find that the quick check fails. Which analysis is correct? The answer is that all analyses are correct. The reasons for this situation and how to interpret the results are described below:

a. **Overturning analysis**. The overturning analysis uses an SMF = 2/3. This value of the SMF produces driving earth pressure forces that approximate at-rest earth pressure forces. The resisting forces may also be set by the user to be 0, at-rest, or some percent of full passive. Therefore, when the program reports that the maximum available base shear has been exceeded, these results are for the set of forces used in the overturning analysis. The driving forces are those computed using an SMF = 2/3. An SMF = 2/3 is equivalent to an FS = 1.5. The SMF and FS are inverses of each other.

b. **Sliding analysis**. The sliding analysis applies a constant FS to all wedges. This means that the driving and resisting forces are calculated for the same FS. As stated earlier, an SMF = 2/3 or an FS = 1.5 will approximate at-rest earth pressure forces. As the FS goes below 1.5, the driving earth pressure forces will decrease and the resisting earth pressure forces will increase. Therefore, for a sliding FS below 1.5, the driving forces will be lower than in the overturning analysis. The resisting forces will more than likely be higher than those reported in the overturning analyses. Therefore, the sliding analysis has lower driving forces and higher resisting forces which result in an FS > 1. This discussion is based upon the assumption that the required FS is below 1.5.

c. **Quick check**. The quick check described in Chapter 4, EM 1110-2-2502, uses the forces computed in the overturning analysis to check

the sliding analysis. The maximum available shear force is divided by the desired FS to arrive at a required shear force. If this required shear force is greater than or equal to the shear force required for equilibrium, the quick check is satisfied and the sliding analysis should report an FS equal or greater than the required FS used in the quick check. It is important to note that the quick check cannot be used for an FS greater than the inverse of the SMF used in the overturning analysis (in most cases then the FS would be 1.5). For an FS < 1.5, why would the quick check fail, but the sliding analysis report an FS > 1? The answer is in the magnitude of the forces that are being compared. In the quick check, the required shear force is compared against the shear force required for equilibrium, which was computed based upon the assumption of an SMF = 2/3. The sliding analysis could produce an FS >1 but <1.5 and have lower driving forces and higher resisting forces than in the overturning analysis.

To conclude the discussion, the following recommendations are made:

a. If the overturning analysis reports that the maximum base shear has been exceeded, the overturning stability must be improved.

b. Just because the quick check fails, does not mean the multiple wedge solution will produce an FS < 1. If the quick check succeeds, the multiple wedge solution will report an FS ≥ FS used in the quick check. If the quick check fails, a multiple wedge solution must be performed.

c. The applicability of the above discussion is limited to an FS ≤ 1.5 (i.e., the inverse of the SMF).

Sliding Analysis

The sliding analysis uses the procedure described in Chapter 4, EM 1110-2-2502. This procedure is a limit equilibrium procedure and is iterative in nature. Critical failure angles for the driving and resisting sides are sought for an assumed FS. The resulting earth forces are summed and if the sum is zero, the system is in equilibrium and the critical FS has been found. A flowchart of this procedure is shown in Figure 32.

Critical failure angles

The process of finding the critical failure angles is an iterative process. Assumed failure angles are used to form wedges. The resulting earth forces corresponding to the assumed failure angles are compared until a critical angle is found. The critical angle is one that produces a maximum driving force for the driving wedge and a minimum resisting force for the

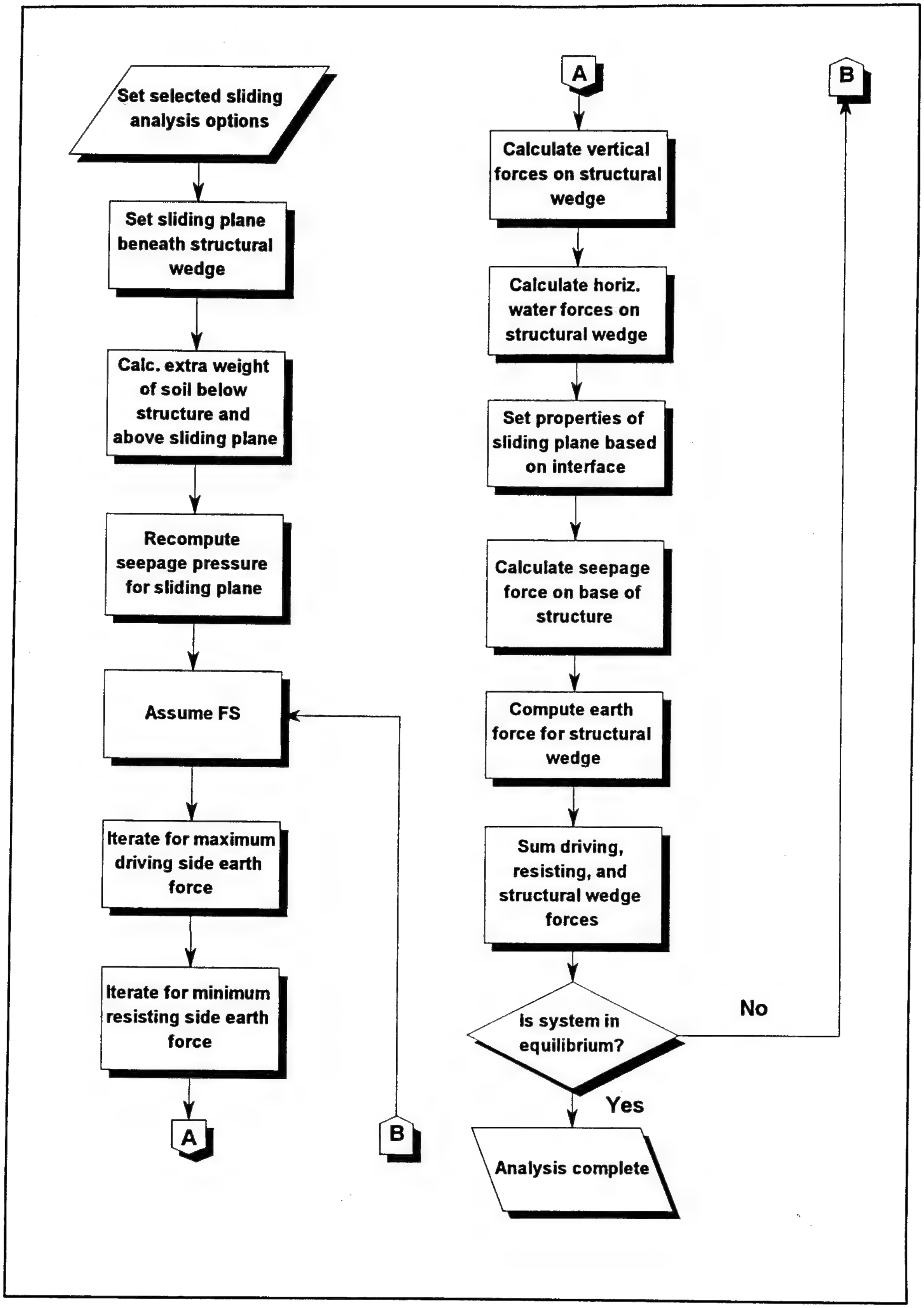


Figure 32. Flowchart of the sliding analysis

resisting wedge. These angles can be different from each other and usually are. The earth pressure forces generated depend upon the assumed FS.

Miscellaneous

Listed below are some miscellaneous information concerning the sliding analysis:

a. For a cohesive material, the critical failure angle for the driving side soil can be made to account for a water-filled crack. There is no crack formed on the resisting side.

b. If the base of the structure is composed of several planes (such as a base with a key), the plane used for the sliding analysis is the plane formed by connecting the extreme left and right corners of the structure by a straight line.

c. If the structure has a base that is a single plane, the values of ϕ and c for the foundation of the soil-structure interface are used in the sliding analysis. If the base of the structure is composed of several planes, the ϕ and c of the soil-soil interface is used in the sliding analysis.

d. The sliding analysis takes into account the percent of base in compression calculated from the overturning analysis. The percent of base in compression affects the normal force developed on the structural wedge. Seepage pressures are also adjusted as previously discussed under the overturning analysis for the percent of base in compression. The only difference is that the seepage pressures are applied to the sliding plane of the structure.

7 Input Guide

Source of Input

Input can be supplied from a prepared data file or from the user's terminal during execution. The entry of data from the terminal is through the use of interactive screen menus.

Data Format

All input data supplied from a data file are read in free-field format. In addition:

a. Data items in a data file must be separated by at least one blank space. Commas are not allowed as delimiters.

b. Integer numbers must be in nondecimal form.

c. Real numbers may be in decimal form, nondecimal form, or E format.

d. A data line may be up to 80 characters long.

Input Sections

Input to the program is divided into required and optional data sections. The various sections of data are:

a. **Required data.** Structural geometry, driving side soil geometry, resisting side soil geometry, properties of the soil, water description, and stability criteria.

b. **Optional data**. Heading information, project data information, unit weight of the structure, vertical surcharge information, horizontal surcharge information, and analysis options.

Sign Convention

The program uses a right-hand coordinate system. Positive angles are taken counter-clockwise from the horizontal and negative angles are taken clockwise from the horizontal. The dimensions and batters entered by the user describing the structure and soil geometry are converted by the program into x,y coordinates. The sign conventions and units for the various dimensions, properties, loads, and moments are shown in Table 1.

Table 1
Units and Sign Conventions

Item	Units	Sign Convention
Horizontal and vertical dimensions	ft	Always positive
Batters	in.:1 ft	Vertical : Horizontal
Unit weights	kcf	Positive or negative
Cohesion	ksf	Always positive
Angle of internal friction	deg	Always positive
Wall friction	deg	Always positive
Failure angles	deg	CW (-), CCW (+) from horizontal
Vertical loads	k/ft	Positive; down
Horizontal loads	kips	Positive; right
Input water pressures	ksf	Positive; up
Moments	ft-kips	CW (+), CCW (-)

Units

All data must be entered in the following units:

a. Length, inches or feet, as directed.

b. Force, kips.

c. Angles, degrees.

All output is given in these same units. Refer to Table 1 for the units associated with the various items of input.

Input Description

The following is an explanation of the command words, variables, requirements, and restrictions for data input. The format given is for input using a data file. If the user is entering data from the terminal, the following format is not needed, since the user will use interactive data input screens. The variables, requirements, and restrictions described are the same if a data file is used or data are entered from the terminal.

Input Syntax

The following syntax should be used when entering data from a data file:

a. Single quotes, ' ', indicate the enclosed information should be typed as shown. All alpha information can be abbreviated to four characters. **BOLD** characters denote the short form of a command word.

b. Brackets, [ ], denote optional information.

c. Asterisks, *, delineate major command sections.

d. All data items must be separated by one or more blank spaces. Do not separate data with commas or any other characters.

e. If any major command word has more than one data line required, the additional lines should immediately follow the major command line.

f. If a subcommand line requires more than one line to enter all the data, a '+' sign should be entered at the end of a the line and the remaining data entered on the following line.

Required Data Description

The following sections of data are required data and must be entered. The structural geometry section must be entered before any other geometry (soil or water). The remaining sections of data can be entered in any order.

Structural geometry

Command lines (4 to 5 lines)

'* **STRUCTURE**' [NSCRN=1]
'**STEM**' ELTS HTS TTS TBS [TBSR]
'**HEEL**' THEEL [BTRH]
'**TOE** ' TTOE TWIDTH [BTRT]
'**BASE**' BWIDTH
['**KEY**' HK TK [BTRK]]

or

'* **STRUCTURE**' [NSCRN=2]
'**STEM**' ELTS TTS TBS [TBSR]
'**HEEL**' THEEL STHEEL
'**TOE** ' ELBT TTOE STTOE TWIDTH
'**BASE**' BWIDTH [BTRB]
['**KEY**' HK TK [BTRK]]

Description (refer to Figures 4 and 5)

'*'	= symbol to denote command section
'STRUCTURE'	= keyword for major command section
NSCRN	= 1 for structural data screen number 1
'STEM'	= keyword for stem data
ELTS	= elevation of top of stem (ft)
HTS	= height of stem (ft)
TTS	= thickness of top of stem (ft)
TBS	= thickness at bottom of stem (ft)
TBSR	= distance of batter at base of stem on the resisting side (ft)
'HEEL'	= keyword for heel data
THEEL	= depth of heel (ft)
BTRH	= distance of batter at end of heel (ft)
'TOE'	= keyword for toe data
TTOE	= depth of toe (ft)
TWIDTH	= width of toe (ft)
BTRT	= distance of batter at end of toe (ft)
'BASE'	= keyword for base data
BWIDTH	= width of base of wall (ft)
'KEY'	= keyword for key data
HK	= depth of key on inside face (resisting side) of key (ft)
TK	= width of bottom of key (ft)
BTRK	= distance of batter at bottom of key (ft)

or

'*'	= symbol to denote command section
'STRUCTURE'	= keyword for major command section
NSCRN	= 2 for sructural data screen number 2
'STEM'	= keyword for stem data
ELTS	= elevation of top of stem (ft)

TTS	= thickness of top of stem (ft)
TBS	= thickness at bottom of stem (ft)
TBSR	= distance of batter at base of stem on the resisting side (ft)
'HEEL'	= keyword for heel data
THEEL	= depth of heel (ft)
STHEEL	= thickness of heel at stem (ft)
'TOE'	= keyword for toe data
ELBT	= elevation of bottom of toe (ft)
TTOE	= depth of toe (ft)
STTOE	= thickness of toe at stem (ft)
TWIDTH	= width of toe (ft)
'BASE'	= keyword for base data
BWIDTH	= width of base of wall (ft)
BTRB	= batter of bottom of base (in:1 ft)
'KEY'	= keyword for key data
HK	= depth of key on inside face (resisting side) of key (ft)
TK	= width of bottom of key (ft)
BTRK	= distance of batter at bottom of key (ft)

Data restrictions

All dimensions must be positive.

Elevations can be positive or negative.

Valid structural configurations are shown in Figure 26.

Valid base types which are accommodated by the program are shown in Figure 27.

Driving side soil data

Command line (1 line)

'* **DRIVING**' ELSTDS BTRDRV(1) [DSTDRV(1) BTRDRV(2) DSTDRV(2) BTRDRV(3)]

Description (refer to Figure 6)

'*'	= symbol to denote command section
'DRIVING'	= keyword for major command section
ELSTDR	= elevation of soil at structure (ft)
BTRDRV(1)	= soil batter at structure (in:1 ft)
DSTDRV(1)	= distance covered by BTRDRV(1) (ft)
BTRDRV(2)	= soil batter adjacent to BTRDRV(1) (in:1 ft)
DSTDRV(2)	= distance covered by BTRDRV(2) (ft)
BTRDRV(3)	= soil batter adjacent to BTRDRV(2) (in:1 ft)

Data restrictions

The distances DSTDRV must be positive.

The elevation of the soil at the structure must be at or above the lower left corner of the structure.

The driving side is always the left side of the problem.

Default values

DSTDRV(1) has an initial value of 500 ft. All soil batters have an initial value of 0.

Comments

The soil data are entered starting with the soil segment at the structure and progressing to the left as shown in Figure 6.

The soil is extended from the structure an additional 500 ft at the angle of the last slope entered and then an additional 500 ft horizontally.

Positive batters slope up; negative batters slope down.

Resisting side soil data

Command line (1 line)

'* **RESISTING**' ELSTRS BTRRES

Description (refer to Figure 4)

'*'	= symbol to denote command section
'RESISTING'	= keyword for major command section
ELSTRS	= elevation of soil at structure (ft)
BTRRES	= soil batter at structure (in:1 ft)

Data restrictions

The elevation of the soil at the structure must be at or above the lower right corner of the structure.

The resisting side is always the right side of the problem.

Default values

The soil batter has a default value of zero.

Comments

The soil data are entered as shown in Figure 6.

The soil is extended from the structure 500 ft at the batter BTRRES and then an additional 500 ft horizontally.

Positive batters slope up; negative batters slope down.

Properties of soil, structure, and water

Command line (4 to 6 lines)

'* **PROP**ERTIES'
'**DRIV**ING' PHID CD GAMMD GAMSD DELTAD
'**FOUN**DATION' PHIF CF PHIFS CFS GAMMF GAMSF
'**RESI**STING' PHIR CR GAMMR GAMSR
'**STRU**CTURE' GAMCON]
'**WATE**R' GAMWAT]

Description (refer to Figure 7)

'*'	= symbol to denote command section
'PROPERTIES'	= keyword for major command section
'DRIVING'	= keyword for driving side soil
PHID	= angle of internal friction (deg)
CD	= cohesion (ksf)
GAMMD	= moist unit weight of soil (kcf)
GAMSD	= saturated unit weight of soil (kcf)
DELTAD	= angle of wall friction (deg)
'FOUNDATION'	= key word for foundation material
PHIF	= angle of base friction for soil-structure interface (deg)
CF	= adhesion value for soil-structure interface (ksf)
PHIFS	= angle of internal friction for soil-soil interface (deg)
CFS	= cohesion value for soil-soil interface (ksf)
'RESISTING'	= keyword for resisting side soil
PHIR	= angle of internal friction (deg)
CR	= cohesion (ksf)
GAMMR	= moist unit weight of soil (kcf)
GAMSR	= saturated unit weight of soil (kcf)
'STRUCTURE'	= keyword for structure material
GAMCON	= unit weight of concrete (kcf)
'WATER'	= keyword for water
GAMWAT	= unit weight of water (kcf)

Data restrictions

The values of the soil, structure, and water properties are positive.

Default values

The default value for the unit weight of concrete is 0.150 kcf.

The default value for the unit weight of water is 0.0624 kcf.

Water data

Command line (2 to 5 lines)

'* **WATER**'
'**ELEVATION**' WATELD WATELR
['**LOC**']
['**PRESSURES**' DW(1) WAPRES(1) ... DW(10) WAPRES(10)]
['**GAMMA**' GAMWAT]

Description (refer to Figures 8 and 9)

'*' = symbol to denote command section

'WATER'	= keyword for major command section
'ELEVATION'	= keyword for water elevations
WATELD	= elevation of water on driving side (ft)
WATELR	= elevation of water on resisting side (ft)
'LOC'	= keyword to select line of creep (default)
'PRESSURES'	= keyword to enter pressures
DW(I)	= horizontal distance from left end of base to pressure (ft)
WAPRES(I)	= value of water pressure at DW(I) (ksf)
'GAMMA'	= keyword to set unit weight of water
GAMWAT	= unit weight of water (kcf)

Data restrictions

The water elevations can be positive or negative.

The water pressures are assumed to act upwards and should be entered as positive values.

The water elevations must be completely above or completely below the soil surfaces on the driving and resisting sides (i.e., the water levels may not intersect a soil layer). Intermediate water levels are allowed. The water levels must also be above the base of the structure.

For input pressures, water pressures must be entered for both corners of the structure and at any breaks in the base of the structure. Pressures can be equal to zero.

The driving side water elevation must be higher than the resisting side water elevation.

Default values

The default value for the unit weight of water is 0.0624 kcf.

The default method of computing pressures is by the line of creep.

Comments

Water elevations are used to compute submerged lengths of the wedges. Therefore, if input pressures are used, the user should take care to enter the appropriate water elevations.

Factors of safety definitions

Command line (1 line)

'* **FS**' FSS PCB

Description (refer to Figure 10)

'*'	= symbol to denote command section
'FS'	= keyword for major command section
FSS	= minimum factor of safety against sliding
PCB	= minimum percentage of base in compression

Comment

These minimum factors of safety are used for comparison to determine if the proposed wall is adequate.

End of Data Input

Command line (1 line)

'* **END**'

Description

'*'	= symbol to denote command section
'END'	= keyword to signify that all data have been entered

Optional Data Description

The following sections of data are optional. The order of entry does not matter.

Header information

Command line (2 to 6 lines)

['* **HEADER**'
'**COMPANY**' CNAME
'**PROJECT**' PNAME
'**LOCATION**' LOCAT

'**WALL**' WALL
'**INITIALS**' INIT]

Description (refer to Figure 12)

'*'	= symbol to denote command section
'HEADER'	= keyword for major command section
'COMPANY'	= keyword for company name
CNAME	= company name (60 char. max)
'PROJECT'	= keyword for project name
PNAME	= project name (60 char. max)
'LOCATION'	= keyword for location
LOCAT	= location (60 char. max)
'WALL'	= keyword for info about wall
WALL	= info about wall (60 char. max)
'INITIALS'	= keyword for designer's initials
INIT	= designer's initials (3 char. max)

Comment

This information is provided as a header on the output information.

Title information

Command line (1 to 5 lines)

['* **TITLE** TITLE]

Description (refer to Figure 13)

'*'	= symbol to denote command section
'TITLE'	= keyword for major command section
TITLE	= up to 5 lines of 60 characters

Comment

The title is printed at the top of the output.

Vertical surcharge loads

Command line (2 to 7 lines)

[* '**VERTICAL SURCHARGES**'
'**STRIP**' DISTSL(1) WSTRIP(1) SMAG(1) ... DISTSL(5) WSTRIP(5) SMAG(5)
'**UNIFORM**' UMAGD]

Description (refer to Figures 15 and 16)

'*'	= symbol to denote command section
'VERTICAL'	= keyword for major command section
'STRIP'	= keyword for strip load
DISTSL(I)	= distance from left side of structure to left end of load (ft)
WSTRIP(I)	= width of strip load (ft)
SMAG(I)	= magnitude of strip load (kips/ft)
'UNIFORM'	= keyword for uniform load
UMAGD	= magnitude of uniform load (kips/ft)

Data restriction

Surcharges can only be located on the driving side of the wall.

Horizontal surcharge loads

Command line (2 to 11 lines)

['* **HORIZ**ONTAL SURCHARGES'
'**PRES**SURE HPRESS(1, 1) HPRESS(1, 2) ... HPRESS(5, 1) HPRESS(5, 2)
'**LINE**' HLINE(1, 1) HLINE(1, 2) ... HLINE(5, 1) HLINE(5, 2)]

Description (refer to Figures 17 and 18)

'*'	= symbol to denote command section
'HORIZONTAL'	= keyword for major command section
'PRESSURE'	= keyword for pressure load
HPRESS(I, 1)	= elevation of pressure applied to structure (ft)
HPRESS(I, 2)	= magnitude of pressure (ksf)
'LINE'	= keyword for line load
HLINE(I, 1)	= elevation of line load (ft)
HLINE(I, 2)	= magnitude of line load (kips/ft)

Data restrictions

The surcharges are assumed to be applied to the structural wedge.

Crack options

Command line (2 to 3 lines)

['* **CRACK** OPTIONS'
'**CRACK** TO **B**OTTOM OF BASE'
'**COMPUTE** CRACK DEPTH'
'**WATER** IN CRACK'
'**NO W**ATER IN CRACKS']

Description (refer to Figure 19)

'*'	= symbol to denote command section
'CRACK'	= keyword for major command section
'CRACK'	= keyword to select full crack depth
'COMPUTE'	= keyword to compute crack depths
'WATER'	= keyword to select water filled cracks
'NO WATER'	= keyword to select no water in cracks

Default

The default is for no crack above the heel and to fill computed cracks with water.

Wedge options

Command line (2 to 4 lines)

['* **WEDGE**'
'ELEVATION' WEDELD
'ANGLE' WEDNO(1) FANG(1) ... WEDNO(3) FANG(3)
'45+-PHI/2' 'YES / NO']

Description (refer to Figure 19 and 28)

'*'	= symbol to denote command section
'WEDGE'	= keyword for major command section
'ELEVATION'	= keyword to set wedge elevation
WEDELD	= elevation of driving wedge at structure (ft)
'ANGLE'	= keyword to set failure angles
WEDNO(I)	= wedge number
FANG(I)	= failure angle of wedge (deg)
'45+-PHI/2'	= keyword to set failure angles base on equation
YES / NO	= Yes to turn option on, no to turn option off

Data restriction

The elevation of the driving wedge at the structure must be at or above the lower left corner of the structure and below the ground surface.

The values of the wedge angles may vary from +85 to -85 deg.

The line defined by the rotation of the angle for the structural wedge must not extend into the interior of the structure.

The input wedge angle must allow the plane formed by the base of the wedge to intersect the soil layer.

Default values

The elevation of the bottom of the failure wedge on the driving side starts at the bottom of the heel.

The default is for the program to automatically calculate the critical failure angles. The '45+-PHI/2' option is initially set to 'NO'.

Comment

The wedges are numbered from left to right (refer to Figure 33). The wedges and failure angles follow this numbering convention. Also, all output from the program also follows this convention.

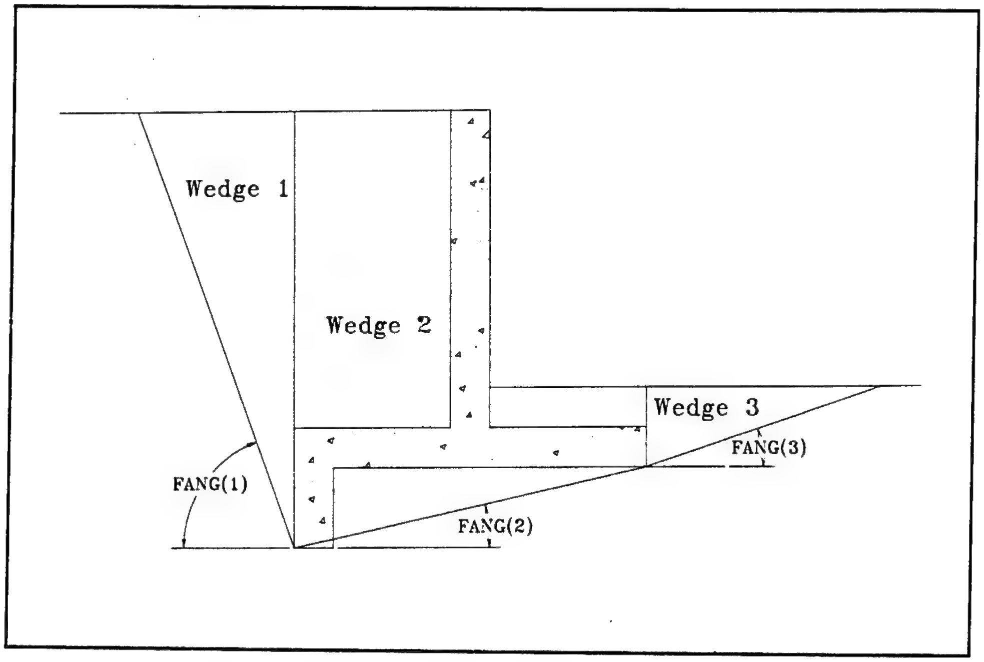


Figure 33. Numbering of wedges and wedge angles

Strength mobilization factor

Command line (1 line)

['* **SMF**' SMF]

Description (refer to Figure 19)

'*'	= symbol to denote command section
'SMF'	= keyword for major command section
SMF	= strength mobilization factor

Default

The default for the SMF = 2/3.

Comment

The SMF entered will be used to compute earth pressures to be used in the overturning analysis.

Amount of resisting side earth force

Command line

['* **PASSIVE** PRESSURE OPTION'
'**OVER**TURNING' 'AT-REST / 0%-50%'
'**SLID**ING' 'NONE / FS']

Description

'*'	= symbol to denote command section
'PASSIVE'	= keyword for major command section
'OVERTURNING'	= keyword for overturning option
'AT-REST'	= command for at-rest pressures
'0%' - '50%'	= selection of percentage of full passive
'SLIDING'	= keyword for sliding option
'NONE'	= no resisting forces used
'FS'	= resisting forces based on FS

Default

At-rest pressures are used in the overturning analysis and resisting forces are based on the FS in the sliding analysis.

The percentages used passive resistance for the overturning option can only be in multiples of 5 percent.

Earth pressure coefficients

Command line

['* **K**' AK PK]

Description

'*'	= symbol to denote command section
'K'	= keyword for major command section
AK	= driving side earth pressure coefficient
PK	= resisting side earth pressure coefficient

Default

The driving side earth pressure coefficient is computed by the program based on the critical failure angle corresponding to the SMF.

The resisting side earth pressure coefficient is calculated using the Danish Code equation.

Force options

Command line

['* **FORCES** CALCULATED'
'**ITER**ATE FOR % BASE IN OVERTURNING'

'**DONT** INTERATE FOR % BASE IN OVERTURNING'
'**FS** FORCES FOR THE REQUIRED FS IN SLIDING'
'CONCENTRATED FORCE FOR EQUILIBRIUM IN SLIDING'
'**NORMAL** ITERATION FOR EQUILIBRIUM IN SLIDING']

Description

'*'	= symbol to denote command section
'FORCES'	= keyword for major command section
'ITERATE'	= keyword to select iteration in overturning analysis
'DONT'	= keyword to prevent iteration in overturning analysis
'FS'	= keyword to select calculation of forces for required FS
'CONC'	= keyword to select calculation of concentrated force required for equilibrium
'NORMAL'	= keyword to select normal equilibrium analysis for sliding

Defaults

The program is initially set for a normal iteration procedure in the sliding analysis and to iterate in the overturning analysis.

Appendix A
Example Problems

General

This appendix contains examples taken from EM 1110-2-2502, Retaining and Flood Walls, ETL 1110-2-322, Retaining and Flood Walls, and Instruction Report ITL-87-5, the CSLIDE user's manual. In the following discussions EM will be used to refer to EM 1110-2-2502, ETL will refer to the ETL 1110-2-322, and CSLIDE user's manual will refer to Instruction Report ITL-87-5. Also, when referring to examples, a letter after an example number refers to the appendix of the corresponding manual. For example, 3M of the EM refers to Example 3 taken from Appendix M of EM 1110-2-2502.

The results from the CTWALL program are given and any differences between the program and manual results are explained.

Example 1

Problem statement

This problem is Example 3M from the EM. The geometry is shown in Figure A1. Soil properties are as follows:

$$\gamma_{moist} = 0.120 \text{ kcf}$$

$$\gamma_{sat} = 0.125 \text{ kcf}$$

$$\gamma_{water} = 0.0625 \text{ kcf}$$

$$\phi = 30°$$

$$c = 0$$

$$SMF = 2/3$$

$$\phi_d = 21°$$

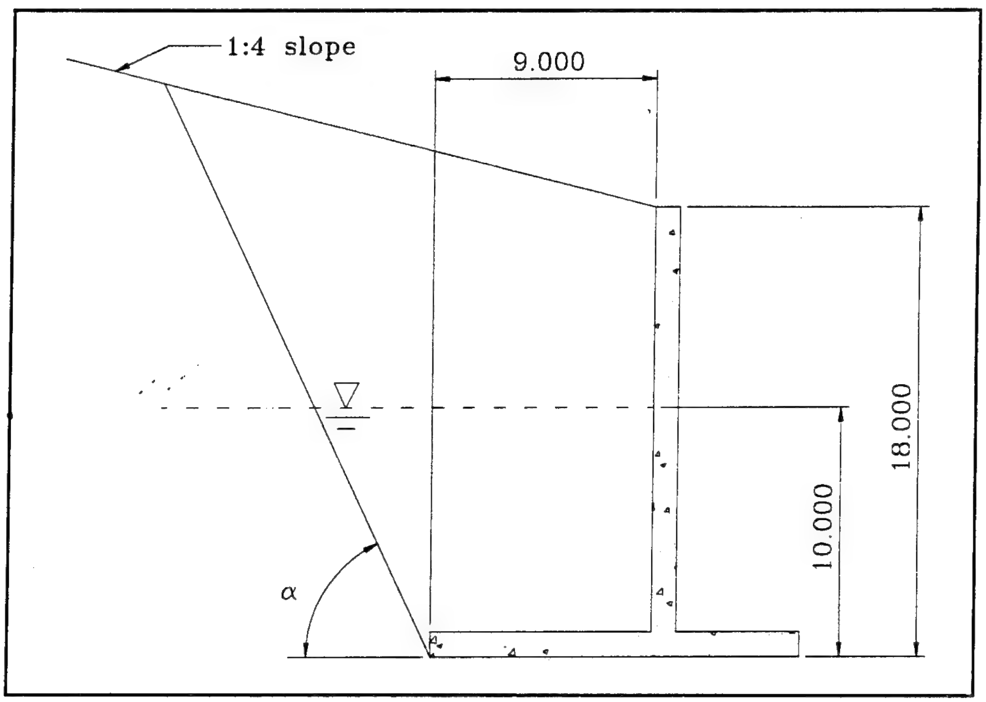


Figure A1. Example problem 1

Discussion of results

For this example, we are concerned only with the overturning results. The CTWALL solution compares exactly with the EM.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                Time:  0.26.39
This is Example 3 from Appendix M of EM 1110-2-2502.
Company name:
  U.S Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide for CTWALL - Example 1
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)          =    18.00 ft
  Height of stem (HTS)                     =    16.00 ft
  Thickness top of stem (TTS)              =     2.00 ft
  Thickness bottom of stem (TBS)           =     2.00 ft
  Dist. of batter at bot. of stem (TBSR)=         .00 ft
  Depth of heel (THEEL)                    =     2.00 ft
  Distance of batter for heel (BTRH)       =      .00 ft
  Depth of toe (TTOE)                      =     2.00 ft
  Width of toe (TWIDTH)                    =     4.25 ft
  Distance of batter for toe (BTRT)        =      .00 ft
  Width of base (BWIDTH)                   =    15.25 ft
  Depth of key (HK)                        =      .00 ft
  Width of bottom of key (TK)              =      .00 ft
  Dist. of batter at bot. of key (BTRK) =         .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00       .00
       .00      2.00
      9.00      2.00
      9.00     18.00
     11.00     18.00
     11.00      2.00
     15.25      2.00
     15.25       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =      .150 kcf
Driving side soil property data:
                         Moist    Saturated           Elev.
   Phi         c        Unit wt.   unit wt.   Delta   soil
  (deg)      (ksf)       (kcf)      (kcf)     (deg)   (ft)
=======================================================
   30.00      .000        .120       .125       .00   18.00
Driving side soil geometry:
  Soil       Batter     Distance
  point     (in:1ft)      (ft)
  =============================
   1          3.00     500.00
   2           .00        .00
   3           .00     500.00
Driving side soil profile:
  Soil          x           y
  point        (ft)        (ft)
  =============================
   1      -1491.00     143.00
   2       -491.00     143.00
   3          9.00      18.00
```

```
Resisting side soil property data:
                               Moist    Saturated  Elev.
    Phi          c          Unit wt.   unit wt.   soil     Batter
   (deg)       (ksf)        (kcf)      (kcf)      (ft)    (in:1ft)
 ========================================================================
      .00       .000        .000       .000       .00       .00
 Resisting side soil profile:
   Soil           x           y
   point        (ft)        (ft)
   =============================
    1           15.25        .00
    2          515.25        .00
 Foundation property data:
   phi for soil-structure interface =     30.00 (deg)
   c for soil-structure interface   =      .000 (ksf)
   phi for soil-soil interface      =     30.00 (deg)
   c for soil-soil interface        =      .000 (ksf)
 Water data:
   Driving side elevation   =    10.00 ft
   Resisting side elevation =    10.00 ft
   Unit weight of water     =    .0625 kcf
   Seepage pressures computed are hydrostatic.
 Minimum required factors of safety:
   Sliding FS    =    1.50
   Overturning   =  100.00% base in compression
 Crack options:
   o  Crack depth is to be calculated
   o  Computed cracks *will* be filled with water
 Strength mobilization factor =     .6667
 At-rest pressures on the resisting side *are used*
 in the overturning analysis.
 Forces on the resisting side *are used* in the sliding analysis.
 *Do* iterate in overturning analysis.
```

Printout of overturning results

```
 ********************** Output Results **********************

 Date: 93/10/30                                    Time:  0.26.39
 This is Example 3 from Appendix M of EM 1110-2-2502.
 Company name:
   U.S Army Corps of Engineers - Waterways Experiment Station
 Project name:
   User's Guide for CTWALL - Example 1
 Project location:
   Vicksburg, MS
 Wall location:

 Computed by: mep
 ***************************
 **  Overturning Results  **
 ***************************
 Solution converged in  2 iterations.
 SMF used to calculate K's =    .6667
 Alpha for the SMF          = -44.3414
 Calculated earth pressure coefficients:
   Driving side at rest K     =    .4405
   Driving side at rest Kc    =    .9767
   Resisting side at rest K   =    .0000
   Resisting side at rest Kc  =    .0000
   At-rest K's for resisting side calculated.
 Depth of cracking =      .00 ft
 ** Driving side pressures **
   Water pressures:
     Elevation    Pressure
       (ft)        (ksf)
     ======================
         10.00       .0000
           .00       .6250
```

```
  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    =====================
        20.25      .0000
        10.00      .7280
          .00     1.1850
** Resisting side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    =====================
        10.00      .0000
          .00      .6250
          .00      .6250
** Uplift pressures **
  Water pressures:
     x-coord.   Pressure
       (ft)       (ksf)
    =====================
          .00      .6250
          .50      .6250
        15.25      .6250
** Forces and moments **
=======================================================================
              Part             |   Force (kips)    | Mom. Arm  |  Moment |
                               |  Vert.   |   Horiz.|   (ft)    |  (ft-k) |
=======================================================================
Structure:
  Structure weight...........    9.375                  -6.41    -60.08
Structure, driving side:
  Moist soil.................    9.855                 -10.93   -107.76
  Saturated soil.............    9.000                 -10.75    -96.75
  Water above structure......     .000                    .00       .00
  Water above soil...........     .000                    .00       .00
  External vertical loads....     .000                    .00       .00
  Ext. horz. pressure loads..                .000         .00       .00
  Ext. horz. line loads......                .000         .00       .00
Structure, resisting side:
  Moist soil.................     .000                    .00       .00
  Saturated soil.............     .000                    .00       .00
  Water above structure......     .000                    .00       .00
  Water above soil...........    2.125                  -2.13     -4.52
Driving side:
  Effective earth loads......              13.296        7.08     94.08
  Shear (due to delta).......     .000                    .00       .00
  Horiz. surcharge effects...                .000         .00       .00
  Water loads................               3.125        3.33     10.42
Resisting side:
  Effective earth loads......                .000         .00       .00
  Water loads................              -3.125        3.33    -10.42
Foundation:
  Vertical force on base.....  -20.824                  -4.92    102.36
  Shear on base..............             -13.296         .00       .00
  Uplift.....................   -9.531                  -7.63     72.68
=======================================================================
** Statics Check **   SUMS =      .000       .000                   .00
Angle of base          =      .00 degrees
Normal force on base =   20.824 kips
Shear force on base  =   13.296 kips
Max. available shear force =   12.023 kips
*** Warning ***  The maximum available shear along the
base of the structure has been exceeded!
Base pressure at x=  14.75 ft from toe =     .0000 ksf
Base pressure at toe                   =    2.8241 ksf
Xr (measured from toe) =     4.92 ft
Resultant ratio        =    .3223
Stem ratio             =    .2787
Base in compression    =    96.70 %
Overturning ratio      =     1.58
Volume of concrete =     2.31 cubic yds/ft of wall
```

NOTE: The engineer shall verify that the computed bearing pressures below the wall do not exceed the allowable foundation bearing pressure, or, perform a bearing capacity analysis using the program CBEAR. Also, the engineer shall verify that the base pressures do not result in excessive differential settlement of the wall foundation.

Example 2

Problem statement

This problem is Example 4M from the EM. The soil geometry is shown in the Figure A2. The soil properties are as follows:

$$\gamma_{moist} = 0.120 \text{ kcf}$$

$$\gamma_{sat} = 0.125 \text{ kcf}$$

$$\gamma_{water} = 0.0625 \text{ kcf}$$

$$\phi = 35°$$

$$c = 0$$

$$SMF = 2/3$$

$$\phi_d = 25°$$

$$V = 6 \text{ k/ft}$$

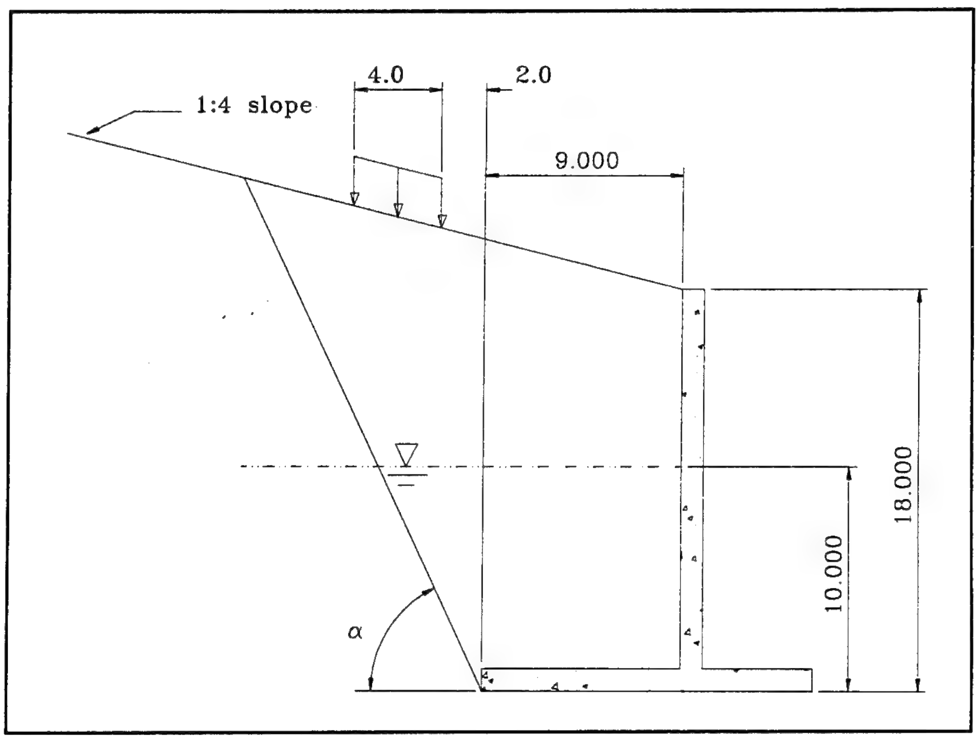


Figure A2. Example problem 2

Discussion of results

The results from CTWALL differ from the EM because the example was computed using the 'lump sum' or approximate method of figuring the distribution of the uniform surcharge. CTWALL uses the elastic method contained in the EM. The equation for a strip surcharge using the elastic method in the EM is in error. The line shown bisecting the angle beta does not necessarily bisect the strip load *q*. Therefore, the corrected equation (and the one CTWALL uses) for alpha is

$$\alpha = \tan^{-1}\left(\frac{x1}{z}\right) + \frac{\beta}{2}$$

This example is concerned only with the pressure distribution on the driving side; therefore, only the overturning results are of interest.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                   Time:  0.27.06
This is Example 4 from Appendix M of EM 1110-2-2502.
Company name:
  U.S Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide for CTWALL - Example 2
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)         =    18.00 ft
  Height of stem (HTS)                    =    16.00 ft
  Thickness top of stem (TTS)             =     2.00 ft
  Thickness bottom of stem (TBS)          =     2.00 ft
  Dist. of batter at bot. of stem (TBSR)  =      .00 ft
  Depth of heel (THEEL)                   =     2.00 ft
  Distance of batter for heel (BTRH)      =      .00 ft
  Depth of toe (TTOE)                     =     2.00 ft
  Width of toe (TWIDTH)                   =     4.25 ft
  Distance of batter for toe (BTRT)       =      .00 ft
  Width of base (BWIDTH)                  =    15.25 ft
  Depth of key (HK)                       =      .00 ft
  Width of bottom of key (TK)             =      .00 ft
  Dist. of batter at bot. of key (BTRK)   =      .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00       .00
       .00      2.00
      9.00      2.00
      9.00     18.00
     11.00     18.00
     11.00      2.00
     15.25      2.00
     15.25       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
```

Driving side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Delta (deg)	Elev. soil (ft)
35.00	.000	.120	.125	.00	18.00

Driving side soil geometry:

Soil point	Batter (in:1ft)	Distance (ft)
1	3.00	500.00
2	.00	.00
3	.00	500.00

Driving side soil profile:

Soil point	x (ft)	y (ft)
1	-1491.00	143.00
2	-491.00	143.00
3	9.00	18.00

Resisting side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Elev. soil (ft)	Batter (in:1ft)
.00	.000	.000	.000	.00	.00

Resisting side soil profile:

Soil point	x (ft)	y (ft)
1	15.25	.00
2	515.25	.00

```
Foundation property data:
  phi for soil-structure interface =    35.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    35.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation    =    16.00 ft
  Resisting side elevation =    16.00 ft
  Unit weight of water      =    .0625 kcf
  Seepage pressures computed are hydrostatic.
```

Strip load data:

Dist. to left end (ft)	Width (ft)	Magnitude (k/ft)
15.00	4.00	1.50

```
Minimum required factors of safety:
  Sliding FS    =     1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                                Time:  0.27.06
This is Example 4 from Appendix M of EM 1110-2-2502.
Company name:
  U.S Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide for CTWALL - Example 2
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  2 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF          = -74.5779
Calculated earth pressure coefficients:
  Driving side at rest K    =    .3236
  Driving side at rest Kc   =    .7782
  Resisting side at rest K  =    .0000
  Resisting side at rest Kc =    .0000
  At-rest K's for resisting side calculated.
Depth of cracking =      .00 ft
** Driving side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)       (ksf)
    ======================
        16.00      .0000
          .00     1.0000
  Earth pressures:
    Elevation   Pressure
      (ft)       (ksf)
    ======================
        20.25      .0000
        16.00      .1773
          .00      .5469
  Surcharge pressures:
       Elev.   Press.
       (ft)    (ksf)
    ===================
        20.25     .000
        19.85     .248
        19.44     .445
        19.03     .568
        18.63     .625
        18.23     .633
        17.62     .593
        17.01     .527
        16.20     .431
        15.19     .327
        14.18     .247
        13.16     .187
        12.15     .143
        11.14     .111
        10.13     .087
         9.11     .070
         8.10     .056
         6.08     .038
         4.05     .027
         2.03     .019
          .00     .014
```

```
** Resisting side pressures **
  Water pressures:
    Elevation    Pressure
      (ft)         (ksf)
    =====================
        16.00      .0000
          .00     1.0000
          .00     1.0000
** Uplift pressures **
  Water pressures:
     x-coord.    Pressure
       (ft)        (ksf)
    =====================
          .00     1.0000
         5.06     1.0000
        15.25     1.0000
** Forces and moments **
=========================================================================
              Part           |     Force (kips)      | Mom. Arm  |  Moment |
                             |  Vert.    |   Horiz.|    (ft)   |  (ft-k) |
=========================================================================
Structure:
  Structure weight...........  9.375                 -6.41    -60.08
Structure, driving side:
  Moist soil.................  3.375                -11.29    -38.10
  Saturated soil............. 15.750                -10.75   -169.31
  Water above structure......   .000                   .00       .00
  Water above soil...........   .000                   .00       .00
  External vertical loads....   .000                   .00       .00
  Ext. horz. pressure loads..              .000        .00       .00
  Ext. horz. line loads......              .000        .00       .00
Structure, resisting side:
  Moist soil.................   .000                   .00       .00
  Saturated soil.............   .000                   .00       .00
  Water above structure......   .000                   .00       .00
  Water above soil...........  3.719                 -2.13     -7.90
Driving side:
  Effective earth loads......             6.170       7.30     45.02
  Shear (due to delta).......   .000                   .00       .00
  Horiz. surcharge effects...             3.667      15.40     56.48
  Water loads................             8.000       5.33     42.67
Resisting side:
  Effective earth loads......              .000        .00       .00
  Water loads................            -8.000       5.33    -42.67
Foundation:
  Vertical force on base..... -16.969                -3.40     57.62
  Shear on base..............            -9.837        .00       .00
  Uplift..................... -15.250                -7.63    116.28
=========================================================================
** Statics Check **   SUMS =    .000       .000                    .00
Angle of base         =       .00 degrees
Normal force on base =   16.969 kips
Shear force on base  =    9.837 kips
Max. available shear force =   11.882 kips
Base pressure at x=  10.19 ft from toe =    .0000 ksf
Base pressure at toe                   =   3.3313 ksf
Xr (measured from toe) =      3.40 ft
Resultant ratio        =     .2227
Stem ratio             =     .2787
Base in compression    =     66.80 %
Overturning ratio      =      1.22
Volume of concrete =      2.31 cubic yds/ft of wall
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Example 3

Problem statement

This problem is Example 5M from the EM. The soil geometry for this problem is shown in Figure A3. The problem has the following soil properties:

$$\gamma_{moist} = 0.120 \text{ kcf}$$

$$\gamma_{sat} = 0.125 \text{ kcf}$$

$$\gamma_{water} = 0.0625 \text{ kcf}$$

$$\phi = 0°$$

$$c = 0.60 \text{ ksf}$$

$$SMF = 2/3$$

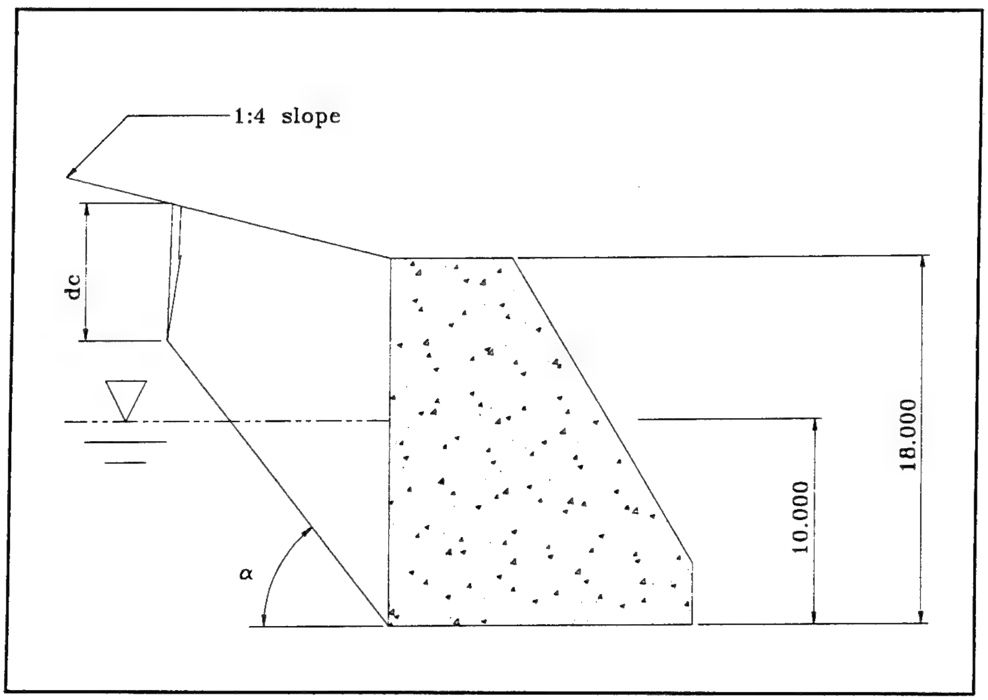


Figure A3. Example problem 3

Discussion of results

CTWALL agrees with the solution in the EM. Since the earth pressure distribution on the driving side is of interest, only the overturning results are presented.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                   Time:  0.27.32
This is Example 5 from Appendix M of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 3
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)        =     18.00 ft
  Height of stem (HTS)                   =     14.00 ft
  Thickness top of stem (TTS)            =      4.50 ft
  Thickness bottom of stem (TBS)         =     14.50 ft
  Dist. of batter at bot. of stem (TBSR)=      10.00 ft
  Depth of heel (THEEL)                  =      4.00 ft
  Distance of batter for heel (BTRH)     =       .00 ft
  Depth of toe (TTOE)                    =      4.00 ft
  Width of toe (TWIDTH)                  =       .00 ft
  Distance of batter for toe (BTRT)      =       .00 ft
  Width of base (BWIDTH)                 =     14.50 ft
  Depth of key (HK)                      =       .00 ft
  Width of bottom of key (TK)            =       .00 ft
  Dist. of batter at bot. of key (BTRK) =       .00 ft
Structure coordinates:
   x (ft)    y (ft)
  ==================
       .00       .00
       .00     18.00
      4.50     18.00
     14.50      4.00
     14.50       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
Driving side soil property data:
                          Moist    Saturated            Elev.
   Phi          c        Unit wt.  unit wt.   Delta     soil
  (deg)       (ksf)       (kcf)     (kcf)     (deg)     (ft)
=======================================================
     .00      .600        .120      .125       .00     18.00
Driving side soil geometry:
  Soil         Batter    Distance
  point       (in:1ft)     (ft)
  ============================
   1          3.00     2000.00
   2           .00         .00
   3           .00      500.00
Driving side soil profile:
  Soil          x          y
  point       (ft)        (ft)
  ============================
   1      -3000.00     518.00
   2      -2000.00     518.00
   3           .00      18.00
Resisting side soil property data:
                          Moist    Saturated   Elev.
   Phi          c        Unit wt.  unit wt.    soil      Batter
  (deg)       (ksf)       (kcf)     (kcf)      (ft)     (in:1ft)
=========================================================
     .00      .000        .000      .000       .00        .00
```

```
Resisting side soil profile:
   Soil         x          y
   point       (ft)       (ft)
   ============================
    1        14.50       .00
    2       514.50       .00
 Foundation property data:
   phi for soil-structure interface =       .00 (deg)
   c for soil-structure interface   =      .600 (ksf)
   phi for soil-soil interface      =       .00 (deg)
   c for soil-soil interface        =      .600 (ksf)
 Water data:
   Driving side elevation   =    10.00 ft
   Resisting side elevation =    10.00 ft
   Unit weight of water     =    .0625 kcf
   Seepage pressures computed are hydrostatic.
 Minimum required factors of safety:
   Sliding FS   =    1.50
   Overturning  =  100.00% base in compression
 Crack options:
   o  Crack depth is to be calculated
   o  Computed cracks *will not* be filled with water
 Strength mobilization factor =    .6667
 At-rest pressures on the resisting side *are used*
 in the overturning analysis.
 Forces on the resisting side *are used* in the sliding analysis.
 *Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                                Time:  0.27.32
This is Example 5 from Appendix M of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 3
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF          = -29.0874
Calculated earth pressure coefficients:
  Driving side at rest K    =  1.0000
  Driving side at rest Kc   =  2.1375
  Resisting side at rest K  =   .0000
  Resisting side at rest Kc =   .0000
  At-rest K's for resisting side calculated.
Depth of cracking =      7.85 ft
** Driving side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)       (ksf)
    =====================
        10.00      .0000
          .00      .6250
```

```
   Earth pressures:
     Elevation   Pressure
       (ft)        (ksf)
     ====================
         18.00       .0000
         10.15       .0000
         10.00       .0335
           .00      1.6379
 ** Resisting side pressures **
   Water pressures:
     Elevation   Pressure
       (ft)        (ksf)
     ====================
         10.00       .0000
           .00       .6250
           .00       .6250
 ** Uplift pressures **
   Water pressures:
      x-coord.   Pressure
        (ft)       (ksf)
     ====================
           .00       .6250
         14.50       .6250
 ** Forces and moments **
=========================================================================
              Part            |    Force (kips)     | Mom. Arm  |  Moment |
                              |  Vert.   |   Horiz.|    (ft)   |  (ft-k) |
=========================================================================
Structure:
  Structure weight...........  28.650                  -8.69    -248.84
Structure, driving side:
  Moist soil.................    .000                    .00        .00
  Saturated soil.............    .000                    .00        .00
  Water above structure......    .000                    .00        .00
  Water above soil...........    .000                    .00        .00
  External vertical loads....    .000                    .00        .00
  Ext. horz. pressure loads..              .000          .00        .00
  Ext. horz. line loads......              .000          .00        .00
Structure, resisting side:
  Moist soil.................    .000                    .00        .00
  Saturated soil.............    .000                    .00        .00
  Water above structure......    .000                    .00        .00
  Water above soil...........    .804                  -1.43      -1.15
Driving side:
  Effective earth loads......             8.360         3.40      28.44
  Shear (due to delta).......    .000                    .00        .00
  Horiz. surcharge effects...              .000          .00        .00
  Water loads................             3.125         3.33      10.42
Resisting side:
  Effective earth loads......              .000          .00        .00
  Water loads................            -3.125         3.33     -10.42
Foundation:
  Vertical force on base..... -20.391                  -7.64     155.84
  Shear on base..............            -8.360          .00        .00
  Uplift.....................  -9.063                  -7.25      65.70
=========================================================================
** Statics Check **   SUMS =     .000       .000                    .00
Angle of base        =      .00 degrees
Normal force on base =   20.391 kips
Shear force on base  =    8.360 kips
Max. available shear force =     8.700 kips
Base pressure at heel =   1.6348 ksf
Base pressure at toe  =   1.1778 ksf
Xr (measured from toe) =      7.64 ft
Resultant ratio        =     .5271
Stem ratio             =     .0000
Base in compression    =    100.00 %
Overturning ratio      =      2.49
Volume of concrete =     7.07 cubic yds/ft of wall
```

NOTE: The engineer shall verify that the computed bearing pressures below the wall do not exceed the allowable foundation bearing pressure, or, perform a bearing capacity analysis using the program CBEAR. Also, the engineer shall verify that the base pressures do not result in excessive differential settlement of the wall foundation.

Example 4

Problem statement

This problem is Example 9M from the EM. The soil geometry for this problem is shown in Figure A4. The soil properties are shown below:

$$\gamma = 0.120 \text{ kcf}$$

$$\phi = 35°$$

$$c = 0 \text{ ksf}$$

$$SMF = 2/3$$

$$\phi_d = 25°$$

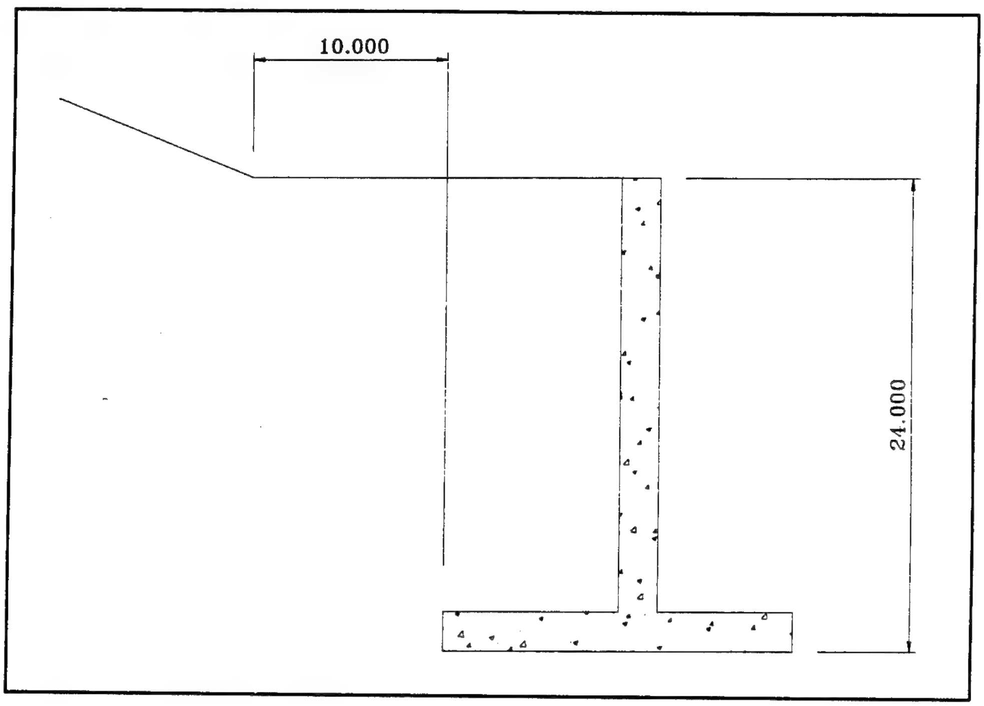


Figure A4. Example problem 4

Discussion of results

Only the overturning results are of interest. CTWALL agrees with the solution contained in the EM.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                Time:  0.33.45
This is Example 9 from Appendix M of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 4
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)        =    24.00 ft
  Height of stem (HTS)                   =    22.00 ft
  Thickness top of stem (TTS)            =     1.90 ft
  Thickness bottom of stem (TBS)         =     2.00 ft
  Dist. of batter at bot. of stem (TBSR) =      .00 ft
  Depth of heel (THEEL)                  =     2.00 ft
  Distance of batter for heel (BTRH)     =      .00 ft
  Depth of toe (TTOE)                    =     2.00 ft
  Width of toe (TWIDTH)                  =     7.00 ft
  Distance of batter for toe (BTRT)      =      .00 ft
  Width of base (BWIDTH)                 =    19.00 ft
  Depth of key (HK)                      =      .00 ft
  Width of bottom of key (TK)            =      .00 ft
  Dist. of batter at bot. of key (BTRK)  =      .00 ft
Structure coordinates:
   x (ft)    y (ft)
  ==================
      .00       .00
      .00      2.00
    10.00      2.00
    10.10     24.00
    12.00     24.00
    12.00      2.00
    19.00      2.00
    19.00       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
Driving side soil property data:
                         Moist   Saturated           Elev.
   Phi         c       Unit wt.  unit wt.   Delta    soil
  (deg)      (ksf)      (kcf)     (kcf)     (deg)    (ft)
=========================================================
   35.00     .000       .120       .120       .00    24.00
Driving side soil geometry:
  Soil       Batter    Distance
  point     (in:1ft)     (ft)
  =============================
   1          .00       20.00
   2         4.80      500.00
   3          .00      500.00
Driving side soil profile:
  Soil         x           y
  point       (ft)        (ft)
  =============================
   1      -1509.90     224.00
   2       -509.90     224.00
   3         -9.90      24.00
   4         10.10      24.00
```

```
Resisting side soil property data:
                           Moist   Saturated  Elev.
   Phi          c        Unit wt.  unit wt.   soil     Batter
  (deg)       (ksf)       (kcf)     (kcf)     (ft)    (in:1ft)
=======================================================
     .00      .000        .000      .000       .00      .00
Resisting side soil profile:
  Soil          x           y
  point        (ft)        (ft)
  =============================
   1         19.00        .00
   2        519.00        .00
Foundation property data:
  phi for soil-structure interface =    35.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    35.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation    =   -10.00 ft
  Resisting side elevation =   -10.00 ft
  Unit weight of water      =    .0624 kcf
  Seepage pressures computed are hydrostatic.
Minimum required factors of safety:
  Sliding FS    =    1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                               Time:  0.33.45
This is Example 9 from Appendix M of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 4
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =     .6667
Alpha for the SMF           = -44.2890
Calculated earth pressure coefficients:
  Driving side at rest K     =    .3583
  Driving side at rest Kc    =    .6873
  Resisting side at rest K  =    .0000
  Resisting side at rest Kc =    .0000
  At-rest K's for resisting side calculated.
Depth of cracking =      .00 ft
```

** Driving side pressures **

Earth pressures:

Elevation (ft)	Pressure (ksf)
24.00	.0000
14.34	.4152
.00	1.4605

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
.00	.0000
19.00	.0000

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight...........	12.135		-8.69	-105.47
Structure, driving side:				
Moist soil.................	26.532		-13.97	-370.78
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
External vertical loads....	.000		.00	.00
Ext. horz. pressure loads..		.000	.00	.00
Ext. horz. line loads......		.000	.00	.00
Structure, resisting side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
Driving side:				
Effective earth loads......		15.457	7.36	113.76
Shear (due to delta).......	.000		.00	.00
Horiz. surcharge effects...		.000	.00	.00
Water loads................		.000	.00	.00
Resisting side:				
Effective earth loads......		.000	.00	.00
Water loads................		.000	.00	.00
Foundation:				
Vertical force on base.....	-38.667		-9.37	362.49
Shear on base..............		-15.457	.00	.00
Uplift.....................	.000		.00	.00
** Statics Check ** SUMS =	.000	.000		.00

Angle of base = .00 degrees
Normal force on base = 38.667 kips
Shear force on base = 15.457 kips
Max. available shear force = 27.075 kips
Base pressure at heel = 1.9546 ksf
Base pressure at toe = 2.1156 ksf
Xr (measured from toe) = 9.37 ft
Resultant ratio = .4934
Stem ratio = .3684
Base in compression = 100.00 %
Overturning ratio = 4.19
Volume of concrete = 3.00 cubic yds/ft of wall
NOTE: The engineer shall verify that the computed bearing pressures below the wall do not exceed the allowable foundation bearing pressure, or, perform a bearing capacity analysis using the program CBEAR. Also, the engineer shall verify that the base pressures do not result in excessive differential settlement of the wall foundation.

Example 5

Problem statement

This problem is Example 10M from the EM. The problem geometry is shown in Figure A5. The soil properties are given below:

$$\gamma = 0.120 \text{ kcf}$$

$$\phi = 35°$$

$$c = 0 \text{ ksf}$$

$$SMF = 2/3$$

$$\phi_d = 25°$$

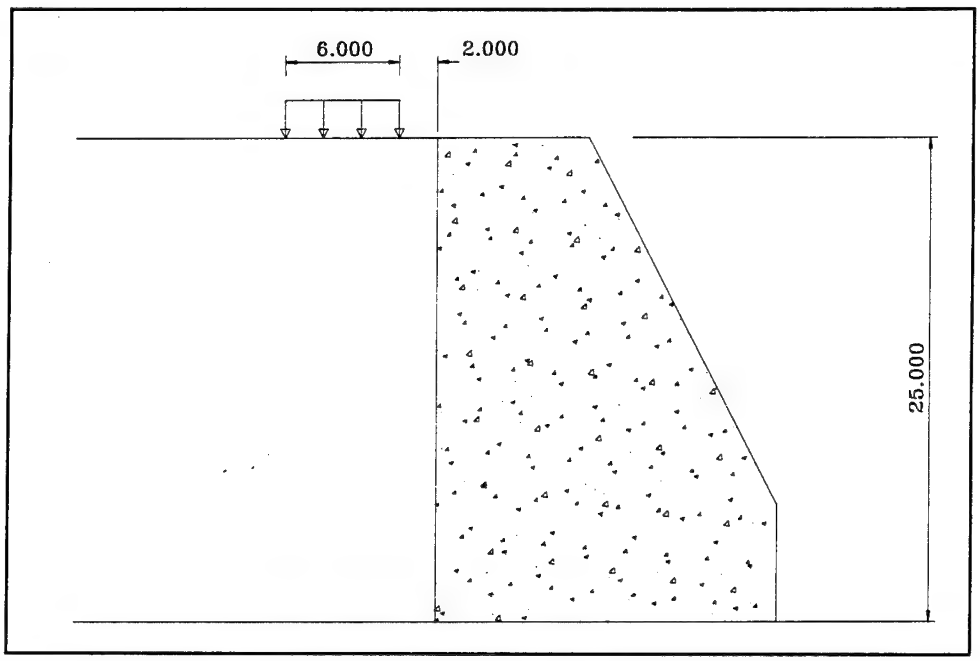


Figure A5. Example problem 5

Discussion of results

The EM calculates the horizontal effects of the vertical surcharge by the elastic method. This is in error as previously discussed in Example 2.

Echoprint of data

```
****************** Echoprint of Input Data *****************

Date: 93/10/30                                    Time:  0.28.29
This is Example 10 from Appendix M of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 5
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)         =    25.00 ft
  Height of stem (HTS)                    =    19.00 ft
  Thickness top of stem (TTS)             =     6.00 ft
  Thickness bottom of stem (TBS)          =    20.00 ft
  Dist. of batter at bot. of stem (TBSR)  =    14.00 ft
  Depth of heel (THEEL)                   =     6.00 ft
  Distance of batter for heel (BTRH)      =      .00 ft
  Depth of toe (TTOE)                     =     6.00 ft
  Width of toe (TWIDTH)                   =      .00 ft
  Distance of batter for toe (BTRT)       =      .00 ft
  Width of base (BWIDTH)                  =    20.00 ft
  Depth of key (HK)                       =      .00 ft
  Width of bottom of key (TK)             =      .00 ft
  Dist. of batter at bot. of key (BTRK)   =      .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00        .00
       .00      25.00
      6.00      25.00
     20.00       6.00
     20.00        .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
Driving side soil property data:
                       Moist    Saturated          Elev.
   Phi         c      Unit wt.  unit wt.  Delta    soil
  (deg)      (ksf)     (kcf)     (kcf)    (deg)    (ft)
=======================================================
   35.00      .000      .120      .125      .00    25.00
Driving side soil geometry:
  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  =============================
   1          .00     500.00
   2          .00        .00
   3          .00     500.00
Driving side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  =============================
   1     -1500.00     25.00
   2          .00     25.00
Resisting side soil property data:
                       Moist    Saturated  Elev.
   Phi         c      Unit wt.  unit wt.   soil    Batter
  (deg)      (ksf)     (kcf)     (kcf)     (ft)   (in:1ft)
========================================================
     .00      .000      .000      .000      .00      .00
```

```
Resisting side soil profile:
  Soil         x           y
  point       (ft)        (ft)
  =============================
    1        20.00        .00
    2       520.00        .00
Foundation property data:
  phi for soil-structure interface =    35.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    35.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation   =   -10.00 ft
  Resisting side elevation =   -10.00 ft
  Unit weight of water     =    .0624 kcf
  Seepage pressures computed are hydrostatic.
Strip load data:
   Dist. to
   left end    Width  Magnitude
     (ft)       (ft)    (k/ft)
================================
     8.00       6.00       .50
Minimum required factors of safety:
  Sliding FS    =    1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                               Time:  0.28.29
This is Example 10 from Appendix M of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 5
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF          = -61.7264
Calculated earth pressure coefficients:
  Driving side at rest K    =    .4009
  Driving side at rest Kc   =    .6417
  Resisting side at rest K  =    .0000
  Resisting side at rest Kc =    .0000
  At-rest K's for resisting side calculated.
Depth of cracking =      .00 ft
```

** Driving side pressures **

Earth pressures:

Elevation (ft)	Pressure (ksf)
25.00	.0000
.00	1.2028

Surcharge pressures:

Elev. (ft)	Press. (ksf)
25.00	.000
24.50	.113
24.00	.196
23.50	.241
23.00	.256
22.50	.253
21.75	.233
21.00	.205
20.00	.168
18.75	.128
17.50	.098
16.25	.075
15.00	.058
13.75	.045
12.50	.036
11.25	.029
10.00	.023
7.50	.016
5.00	.011
2.50	.008
.00	.006

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
.00	.0000
20.00	.0000

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight...........	55.050		-11.93	-656.90
Structure, driving side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
External vertical loads....	.000		.00	.00
Ext. horz. pressure loads..		.000	.00	.00
Ext. horz. line loads......		.000	.00	.00
Structure, resisting side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
Driving side:				
Effective earth loads......		15.035	8.33	125.30
Shear (due to delta).......	.000		.00	.00
Horiz. surcharge effects...		1.829	19.02	34.78
Water loads................		.000	.00	.00
Resisting side:				
Effective earth loads......		.000	.00	.00
Water loads................		.000	.00	.00

```
Foundation:
  Vertical force on base.....  -55.050                          -9.03    496.83
  Shear on base.............                -16.864               .00       .00
  Uplift....................      .000                            .00       .00
=======================================================================
** Statics Check **   SUMS =      .000        .000                          .00
Angle of base          =      .00 degrees
Normal force on base =   55.050 kips
Shear force on base  =   16.864 kips
Max. available shear force =   38.546 kips
Base pressure at heel =   1.9474 ksf
Base pressure at toe  =   3.5576 ksf
Xr (measured from toe) =     9.03 ft
Resultant ratio         =    .4513
Stem ratio              =    .0000
Base in compression     =   100.00 %
Overturning ratio       =     4.10
Volume of concrete =    13.59 cubic yds/ft of wall
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Example 6

Problem statement

This problem is Example 1N from the EM. The soil geometry is shown in Figure A6, and the soil properties are shown below:

Backfill:

$$\gamma = 0.120 \text{ kcf}$$

$$\phi = 35°$$

$$c = 0 \text{ ksf}$$

Foundation:

$$\gamma = 0.135 \text{ kcf}$$

$$\phi = 40°$$

$$c = 0 \text{ ksf}$$

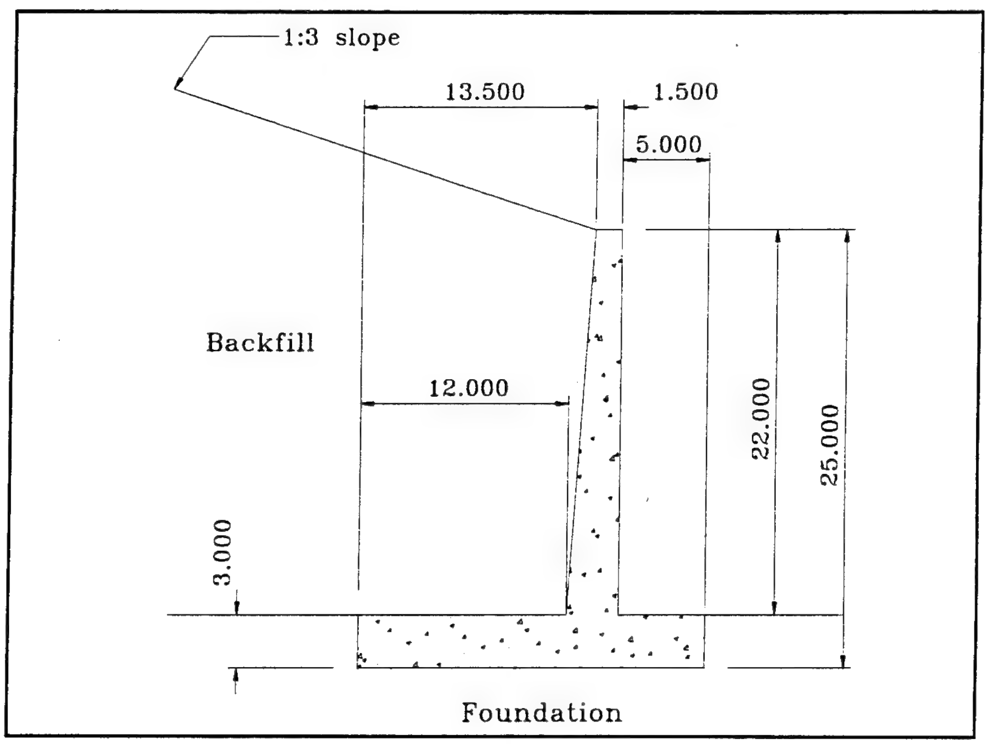


Figure A6. Example problem 6

Discussion of results

The earth pressures calculated in the EM example do not agree with the CTWALL output. This is because CTWALL is limited to a single soil layer in the backfill and cannot account for the foundation layer. Also, a wall friction angle of 6.33 deg was used to approximate the method of adding a shear force on the structural wedge as described in the EM. These differences account for the slight differences in the answers.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                   Time:  0.28.51
This is Example 1 from Appendix N of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 6
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)       =     25.00 ft
  Height of stem (HTS)                  =     22.00 ft
  Thickness top of stem (TTS)           =      1.50 ft
  Thickness bottom of stem (TBS)        =      3.00 ft
  Dist. of batter at bot. of stem (TBSR)=       .00 ft
  Depth of heel (THEEL)                 =      3.00 ft
  Distance of batter for heel (BTRH)    =       .00 ft
  Depth of toe (TTOE)                   =      3.00 ft
  Width of toe (TWIDTH)                 =      5.00 ft
  Distance of batter for toe (BTRT)     =       .00 ft
  Width of base (BWIDTH)                =     20.00 ft
  Depth of key (HK)                     =       .00 ft
  Width of bottom of key (TK)           =       .00 ft
  Dist. of batter at bot. of key (BTRK) =       .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00        .00
       .00       3.00
     12.00       3.00
     13.50      25.00
     15.00      25.00
     15.00       3.00
     20.00       3.00
     20.00        .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =      .150 kcf
Driving side soil property data:
                        Moist   Saturated          Elev.
   Phi         c       Unit wt.  unit wt.   Delta   soil
  (deg)      (ksf)      (kcf)     (kcf)     (deg)   (ft)
=======================================================
   35.00      .000       .120      .125      6.33   25.00
```

```
Driving side soil geometry:
  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  ============================
   1          4.00    500.00
   2           .00       .00
   3           .00    500.00
Driving side soil profile:
  Soil         x           y
  point       (ft)        (ft)
  ============================
   1      -1486.50    191.67
   2       -486.50    191.67
   3         13.50     25.00
Resisting side soil property data:
                     Moist   Saturated  Elev.
   Phi         c    Unit wt.  unit wt.  soil    Batter
  (deg)      (ksf)   (kcf)     (kcf)    (ft)   (in:1ft)
=======================================================
   40.00      .000    .135      .140     3.00     .00
Resisting side soil profile:
  Soil         x           y
  point       (ft)        (ft)
  ============================
   1        20.00       3.00
   2       520.00       3.00
Foundation property data:
  phi for soil-structure interface =    40.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    35.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation   =   -10.00 ft
  Resisting side elevation =   -10.00 ft
  Unit weight of water     =    .0624 kcf
  Seepage pressures computed are hydrostatic.
Minimum required factors of safety:
  Sliding FS   =    1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =    .6667
Resisting side pressures *are not* used in the overturning analysis.
Forces on the resisting side *are not* used in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                               Time:  0.28.51
This is Example 1 from Appendix N of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 6
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF          = -44.9242
```

```
Calculated earth pressure coefficients:
  Driving side at rest K    =    .3490
  Driving side at rest Kc   =    .9853
  Resisting side at rest K  =    .0000
  Resisting side at rest Kc =    .0000
  No passive pressures used for resisting side.
Depth of cracking =      .00 ft
** Driving side pressures **
  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        29.50      .0000
          .00     1.8554
** Uplift pressures **
  Water pressures:
     x-coord.   Pressure
       (ft)       (ksf)
    ======================
          .00      .0000
        20.00      .0000
** Forces and moments **
========================================================================
             Part             |   Force (kips)     | Mom. Arm  |  Moment |
                              |  Vert.   |   Horiz.|   (ft)    |  (ft-k) |
========================================================================
Structure:
  Structure weight...........   16.425                  -8.27   -135.79
Structure, driving side:
  Moist soil.................   37.305                 -13.80   -514.87
  Saturated soil.............     .000                    .00       .00
  Water above structure......     .000                    .00       .00
  Water above soil...........     .000                    .00       .00
  External vertical loads....     .000                    .00       .00
  Ext. horz. pressure loads..                 .000        .00       .00
  Ext. horz. line loads......                 .000        .00       .00
Structure, resisting side:
  Moist soil.................     .000                    .00       .00
  Saturated soil.............     .000                    .00       .00
  Water above structure......     .000                    .00       .00
  Water above soil...........     .000                    .00       .00
Driving side:
  Effective earth loads......               27.367       9.83    269.11
  Shear (due to delta).......    3.036                 -20.00    -60.72
  Horiz. surcharge effects...                 .000        .00       .00
  Water loads................                 .000        .00       .00
Resisting side:
  Effective earth loads......                 .000        .00       .00
  Water loads................                 .000        .00       .00
Foundation:
  Vertical force on base.....  -56.766                  -7.79    442.26
  Shear on base..............              -27.367        .00       .00
  Uplift.....................     .000                    .00       .00
========================================================================
** Statics Check **   SUMS =      .000        .000                  .00
Angle of base         =       .00 degrees
Normal force on base =    56.766 kips
Shear force on base  =    27.367 kips
Max. available shear force =    47.632 kips
Base pressure at heel =     .9573 ksf
Base pressure at toe  =    4.7193 ksf
Xr (measured from toe) =      7.79 ft
Resultant ratio        =     .3895
Stem ratio             =     .2500
Base in compression    =    100.00 %
Overturning ratio      =      2.64
Volume of concrete =       4.06 cubic yds/ft of wall
```

```
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Printout of the sliding results

```
**********************
**  Sliding Results  **
**********************
Solution converged.  Summation of forces = 0.
           Horizontal    Vertical
  Wedge       Loads        Loads
  Number     (kips)       (kips)
  ===============================
     1         .000         .000
     2         .000         .000
     3         .000         .000
  Water pressures on wedges:
               Top       Bottom
    Wedge    press.    press.   x-coord.      press.
    number   (ksf)     (ksf)      (ft)        (ksf)
  ==============================================
      1     .0000     .0000
      2                           .0000        .0000
      2                         20.0000        .0000
      3     .0000     .0000
Points of sliding plane:
  Point 1 (left),  x =      .00 ft,    y =      .00 ft
  Point 2 (right), x =    20.00 ft,    y =      .00 ft
Depth of cracking =      .00 ft
          Failure    Total    Weight     Submerged    Uplift
  Wedge    angle    length   of wedge     length      force
  number   (deg)     (ft)     (kips)       (ft)       (kips)
  ======================================================
     1   -43.286    66.592    85.801       .000        .000
     2      .000    20.000    53.730       .000        .000
     3      .000      .000      .000       .000        .000
  Wedge     Net force
  number     (kips)
  ==================
     1      -28.776
     2       28.776
     3         .000
  ==================
    SUM =      .000
+----------------+
| Factor of safety =     1.567 |
+----------------+
```

Example 7

Problem statement

This problem is Example 2N from the EM. The structure and soil geometry is shown in Figure A7, and the soil properties are given below:

Backfill:

$$\gamma_{moist} = 0.120 \text{ kcf}$$

$$\gamma_{sat} = 0.125 \text{ kcf}$$

$$\phi = 35°$$

$$c = 0 \text{ ksf}$$

Foundation:

$$\gamma = 0.140 \text{ kcf}$$

$$\phi = 40°$$

$$c = 2.5 \text{ ksf}$$

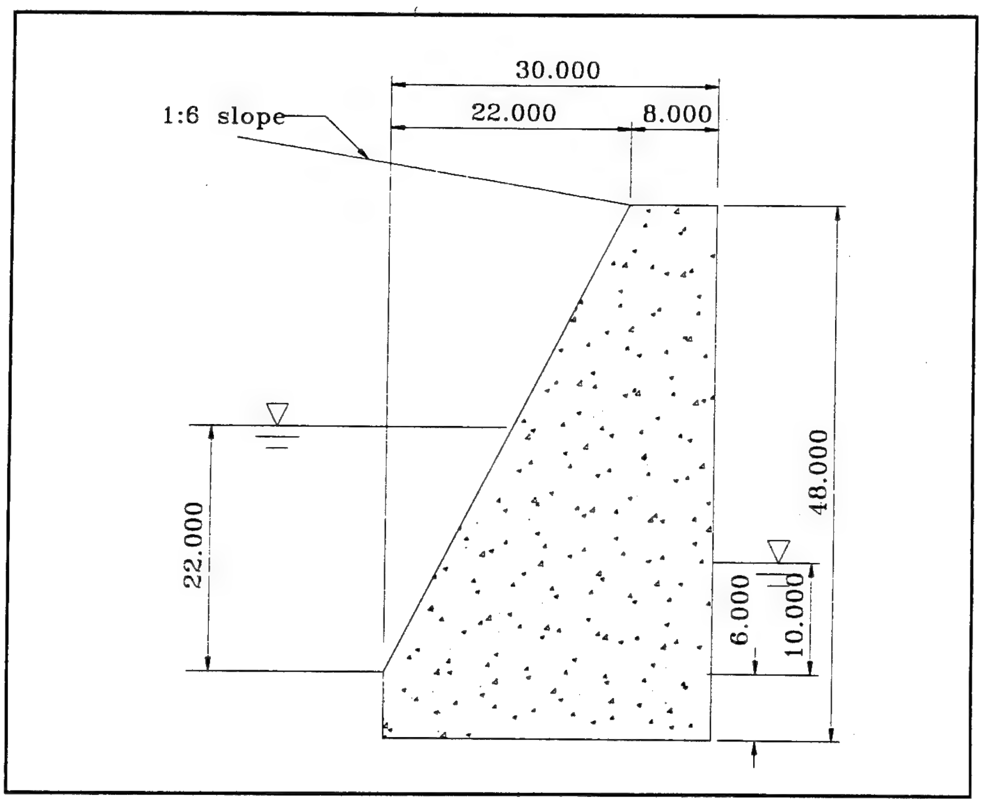


Figure A7. Example problem 7

Discussion of results

The results from CTWALL differ slightly from the solution in the EM. The differences are due to a small difference in the critical failure angle of the driving side. This results in slightly different earth pressure coefficients.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                              Time:  0.29.13
This is Example 2 of Appendix N of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 7
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)        =    48.00 ft
  Height of stem (HTS)                   =    42.00 ft
  Thickness top of stem (TTS)            =     8.00 ft
  Thickness bottom of stem (TBS)         =    30.00 ft
  Dist. of batter at bot. of stem (TBSR) =      .00 ft
  Depth of heel (THEEL)                  =     6.00 ft
  Distance of batter for heel (BTRH)     =      .00 ft
  Depth of toe (TTOE)                    =     6.00 ft
  Width of toe (TWIDTH)                  =      .00 ft
  Distance of batter for toe (BTRT)      =      .00 ft
  Width of base (BWIDTH)                 =    30.00 ft
  Depth of key (HK)                      =      .00 ft
  Width of bottom of key (TK)            =      .00 ft
  Dist. of batter at bot. of key (BTRK)  =      .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00        .00
       .00       6.00
     22.00      48.00
     30.00      48.00
     30.00        .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
Driving side soil property data:
                         Moist   Saturated          Elev.
   Phi         c       Unit wt.  unit wt.  Delta    soil
  (deg)      (ksf)      (kcf)     (kcf)    (deg)    (ft)
=======================================================
   35.00      .000       .120      .125      .00    48.00
Driving side soil geometry:
  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  ============================
   1         2.00    500.00
   2          .00       .00
   3          .00    500.00
```

```
Driving side soil profile:
  Soil        x          y
  point      (ft)       (ft)
  ============================
   1     -1478.00    131.33
   2      -478.00    131.33
   3        22.00     48.00
Resisting side soil property data:
                      Moist   Saturated  Elev.
   Phi         c     Unit wt.  unit wt.  soil     Batter
  (deg)      (ksf)    (kcf)     (kcf)    (ft)   (in:1ft)
=======================================================
    .00      .000     .000      .000     6.00     .00
Resisting side soil profile:
  Soil        x          y
  point      (ft)       (ft)
  ============================
   1        30.00      6.00
   2       530.00      6.00
Foundation property data:
  phi for soil-structure interface =    40.00 (deg)
  c for soil-structure interface   =    2.500 (ksf)
  phi for soil-soil interface      =    40.00 (deg)
  c for soil-soil interface        =    2.500 (ksf)
Water data:
  Driving side elevation    =    28.00 ft
  Resisting side elevation =    16.00 ft
  Unit weight of water      =    .0625 kcf
  Input water pressures:
         Distance   Pressure
  Point    (ft)       (ksf)
  ==========================
   1        .00      1.7500
   2      30.00      1.0000
Minimum required factors of safety:
  Sliding FS    =    1.33
  Overturning  =   75.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Elevation of bottom of driving wedge specified as =    6.00 ft
Strength mobilization factor =     .6667
Resisting side pressures *are not* used in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                               Time:  0.29.13
This is Example 2 of Appendix N of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 7
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  4 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF           = -53.0361
```

```
Calculated earth pressure coefficients:
  Driving side at rest K     =    .4004
  Driving side at rest Kc    =    .7344
  Resisting side at rest K   =    .0000
  Resisting side at rest Kc  =    .0000
  No passive pressures used for resisting side.
Depth of cracking =      .00 ft
** Driving side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        28.00      .0000
          .00     1.7500
  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        51.67      .0000
        28.00     1.3001
         6.00     2.1857
** Resisting side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        16.00      .0000
         6.00      .6250
          .00     1.0000
** Uplift pressures **
  Water pressures:
     x-coord.   Pressure
       (ft)       (ksf)
    ======================
          .00     1.7500
        12.39     1.7500
        30.00     1.0000
** Forces and moments **
=========================================================================
              Part             |   Force (kips)     | Mom. Arm  |  Moment |
                               |  Vert.   |  Horiz.|   (ft)    |  (ft-k) |
=========================================================================
Structure:
  Structure weight...........  146.700                 -11.38  -1669.20
Structure, driving side:
  Moist soil.................   45.069                 -21.49   -968.43
  Saturated soil.............   15.845                 -26.16   -414.49
  Water above structure......     .000                    .00       .00
  Water above soil...........     .000                    .00       .00
  External vertical loads....     .000                    .00       .00
  Ext. horz. pressure loads..                .000         .00       .00
  Ext. horz. line loads......                .000         .00       .00
Structure, resisting side:
  Moist soil.................     .000                    .00       .00
  Saturated soil.............     .000                    .00       .00
  Water above structure......     .000                    .00       .00
  Water above soil...........     .000                    .00       .00
Driving side:
  Effective earth loads......              53.728       21.74   1168.26
  Shear (due to delta).......     .000                    .00       .00
  Horiz. surcharge effects...                .000         .00       .00
  Water loads................              24.500        9.33    228.67
Resisting side:
  Effective earth loads......                .000         .00       .00
  Water loads................              -8.000        5.33    -42.67
Foundation:
  Vertical force on base..... -161.717                  -5.87    949.13
  Shear on base..............             -70.228         .00       .00
  Uplift.....................  -45.897                 -16.31    748.74
=========================================================================
** Statics Check **   SUMS =      .000       .000                   .00
```

```
Angle of base          =       .00 degrees
Normal force on base =  161.717 kips
Shear force on base  =   70.228 kips
Max. available shear force =  179.715 kips
Base pressure at x=  17.61 ft from toe =     .0000 ksf
Base pressure at toe                     =  18.3695 ksf
Xr (measured from toe) =      5.87 ft
Resultant ratio         =    .1956
Stem ratio              =    .0000
Base in compression     =    58.69 %
Overturning ratio       =     1.44
Volume of concrete =     36.22 cubic yds/ft of wall
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Printout of the sliding results

```
***********************
**  Sliding Results  **
***********************
Solution converged.  Summation of forces = 0.
           Horizontal    Vertical
  Wedge      Loads        Loads
  Number     (kips)       (kips)
  ==================================
     1        .000         .000
     2      -3.125         .000
     3        .000        4.282
  Water pressures on wedges:
              Top       Bottom
    Wedge    press.    press.    x-coord.      press.
    number   (ksf)     (ksf)      (ft)         (ksf)
  ================================================
     1      .0000     1.3750
     2                             .0000       1.7500
     2                           12.3911       1.7500
     2                           30.0000       1.0000
     3      .6250     1.0000
Points of sliding plane:
  Point 1 (left),  x =      .00 ft,   y =       .00 ft
  Point 2 (right), x =    30.00 ft,   y =       .00 ft
Depth of cracking =      .00 ft
           Failure    Total     Weight     Submerged    Uplift
  Wedge     angle     length   of wedge     length      force
  number    (deg)      (ft)     (kips)       (ft)       (kips)
  ========================================================
     1    -44.724    78.025    153.120     31.263      21.494
     2       .000    30.000    207.614     30.000      45.897
     3     41.209     9.107       .000      9.107       7.400
  Wedge     Net force
  number     (kips)
  ===================
     1      -86.715
     2       82.965
     3        3.750
  ===================
    SUM =       .000
+----------------+
| Factor of safety =    2.251 |
+----------------+
```

Example 8

Problem statement

This problem is Example 3N from the EM. The soil geometry is shown in Figure A8, and the soil properties are:

$$\gamma_{sat} = 0.120 \text{ kcf}$$

$$\phi = 0°$$

$$c = 0.9 \text{ ksf}$$

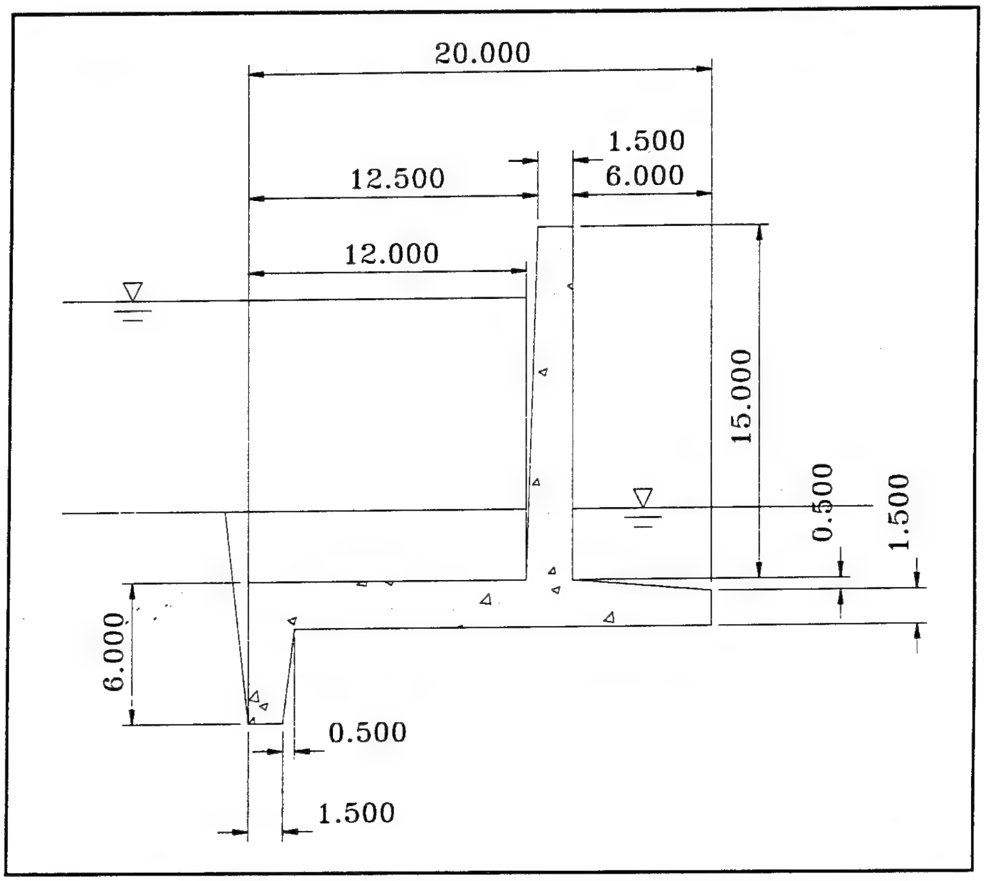


Figure A8. Example problem 8

Discussion of results

The EM shows a value of 25.37 kips for the weight of the structural wedge. CTWALL calculates a value of 24.32 kips for the weight of the structural wedge. The unit weight of the concrete was assumed to be 0.15 kcf. Using this value of unit weight results in this slight difference.

This difference also affects the location of the resultant of the weight of the structural wedge. The final differences are seen in the location of the resultant on the base of the structure. The EM reports 7.87 ft and CTWALL calculates 7.59 ft.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                   Time:  0.29.34
This is Example 3 of Appendix N of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 8
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)         =    21.00 ft
  Height of stem (HTS)                    =    15.00 ft
  Thickness top of stem (TTS)             =     1.50 ft
  Thickness bottom of stem (TBS)          =     2.00 ft
  Dist. of batter at bot. of stem (TBSR)  =      .00 ft
  Depth of heel (THEEL)                   =     6.00 ft
  Distance of batter for heel (BTRH)      =      .00 ft
  Depth of toe (TTOE)                     =     1.50 ft
  Width of toe (TWIDTH)                   =     6.00 ft
  Distance of batter for toe (BTRT)       =      .50 ft
  Width of base (BWIDTH)                  =    20.00 ft
  Depth of key (HK)                       =     4.00 ft
  Width of bottom of key (TK)             =     1.50 ft
  Dist. of batter at bot. of key (BTRK)   =      .50 ft
Structure coordinates:
   x (ft)    y (ft)
  =================
      .00       .00
      .00      6.00
    12.00      6.00
    12.50     21.00
    14.00     21.00
    14.00      6.00
    20.00      5.50
    20.00      4.00
     2.00      4.00
     1.50       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =      .150 kcf
Driving side soil property data:
                       Moist   Saturated          Elev.
   Phi        c       Unit wt.  unit wt.   Delta   soil
  (deg)     (ksf)      (kcf)     (kcf)     (deg)   (ft)
=======================================================
  28.00     .000       .120      .120      .00     9.00
Driving side soil geometry:
  Soil       Batter    Distance
  point     (in:1ft)     (ft)
  ===========================
  1           .00      500.00
  2           .00         .00
  3           .00      500.00
```

```
Driving side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  ============================
   1     -1487.90      9.00
   2        12.10      9.00
Resisting side soil property data:
                    Moist   Saturated  Elev.
   Phi        c    Unit wt.  unit wt.  soil    Batter
  (deg)     (ksf)   (kcf)     (kcf)    (ft)   (in:1ft)
=======================================================
   28.00     .000    .120      .120     9.00     .00
Resisting side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  ============================
   1        14.00      9.00
   2       514.00      9.00
Foundation property data:
  phi for soil-structure interface =    28.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    28.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation   =    18.00 ft
  Resisting side elevation =     9.00 ft
  Unit weight of water     =    .0625 kcf
  Seepage pressures computed by Line of Creep method.
Minimum required factors of safety:
  Sliding FS   =    1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack *is* down to bottom of heel
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Echoprint of overturning analysis

```
********************** Output Results **********************

Date: 93/10/30                              Time:  0.29.34
This is Example 3 of Appendix N of EM 1110-2-2502.
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 8
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF         =    .0000
Calculated earth pressure coefficients:
  Driving side at rest K    =    .0000
  Driving side at rest Kc   =    .0000
  Resisting side at rest K  =    .5305
  Resisting side at rest Kc =    .7284
  At-rest K's for resisting side calculated.
Depth of cracking =     9.00 ft
Crack extends to bottom of base of structure.
```

```
** Driving side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        18.00      .0000
          .00     1.1250
** Resisting side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         9.00      .0000
         4.00      .4232
         4.00      .7688
          .00     1.0962
  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         9.00      .0000
         4.00      .0938
  Balancing earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         4.00     1.2756
          .00     1.2756
** Uplift pressures **
  Water pressures:
     x-coord.   Pressure
       (ft)       (ksf)
    ======================
          .00     1.1250
         1.50     1.0962
         2.00      .7688
        20.00      .4232
** Forces and moments **
=========================================================================
              Part            |   Force (kips)    | Mom. Arm  |  Moment |
                              |  Vert.   |   Horiz.|   (ft)    |  (ft-k) |
=========================================================================
Structure:
  Structure weight..........   10.763                  -9.92   -106.72
Structure, driving side:
  Moist soil................     .000                    .00       .00
  Saturated soil............    4.338                 -13.97    -60.62
  Water above structure.....     .000                    .00       .00
  Water above soil..........    6.891                 -13.87    -95.61
  External vertical loads...     .000                    .00       .00
  Ext. horz. pressure loads..              .000          .00       .00
  Ext. horz. line loads......              .000          .00       .00
Structure, resisting side:
  Moist soil................     .000                    .00       .00
  Saturated soil............    2.340                  -2.92     -6.84
  Water above structure.....     .000                    .00       .00
  Water above soil..........     .000                    .00       .00
Driving side:
  Effective earth loads......              .000          .00       .00
  Shear (due to delta).......    .000                    .00       .00
  Horiz. surcharge effects...              .000          .00       .00
  Water loads................            10.125         2.00     20.25
Resisting side:
  Effective earth loads......             -.234         1.67      -.39
  Balancing earth load.......            -5.102        -2.00     10.20
  Water loads................            -4.788        -1.28      6.13
Foundation:
  Vertical force on base.....  -11.470                 -7.59     87.11
  Uplift.....................  -12.861                -11.39    146.48
=========================================================================
** Statics Check **    SUMS =     .000     .000                    .00
```

```
Angle of base         =    11.31 degrees
Normal force on base =   12.248 kips
Shear force on base  =    2.754 kips
Max. available shear force =    8.577 kips
Base pressure at heel =    .1597 ksf
Base pressure at toe  =    .9874 ksf
Xr (measured from toe) =     7.59 ft
Resultant ratio        =    .3797
Stem ratio             =    .3000
Base in compression    =   100.00 %
Overturning ratio      =     1.56
Volume of concrete =     2.66 cubic yds/ft of wall
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Printout of sliding results

```
***********************
**  Sliding Results  **
***********************
Solution converged.  Summation of forces = 0.
           Horizontal   Vertical
  Wedge       Loads       Loads
  Number     (kips)       (kips)
  =================================
     1         .000         .000
     2       10.125        6.891
     3         .000         .000
  Water pressures on wedges:
              Top      Bottom
    Wedge    press.    press.    x-coord.    press.
    number   (ksf)     (ksf)      (ft)       (ksf)
  ===============================================
      1      .0000     .0000
      2                            .0000     1.1250
      2                          20.0000      .4232
      3      .0000     .4232
Points of sliding plane:
  Point 1 (left),  x =       .00 ft,    y =      .00 ft
  Point 2 (right), x =     20.00 ft,    y =     4.00 ft
Depth of cracking =      9.00 ft
Crack extends to bottom of base of structure.
           Failure    Total     Weight    Submerged    Uplift
  Wedge     angle     length   of wedge    length      force
  number    (deg)      (ft)     (kips)      (ft)       (kips)
  =======================================================
     1       .000       .000       .000       .000       .000
     2     11.310     20.396     21.401     20.396     15.789
     3     39.424      7.873      1.825      7.873      1.666
  Wedge      Net force
  number      (kips)
  ==================
     1          .000
     2        -1.713
     3         1.714
  ==================
    SUM =       .001
+----------------+
| Factor of safety =     2.678 |
+----------------+
```

Example 9

Problem statement

This problem is Example 4N from the EM. The problem geometry is shown in Figure A9. The soil properties are shown below:

$\gamma_{sat} = 0.120$ kcf

$\phi = 0°$

$c = 0.9$ ksf

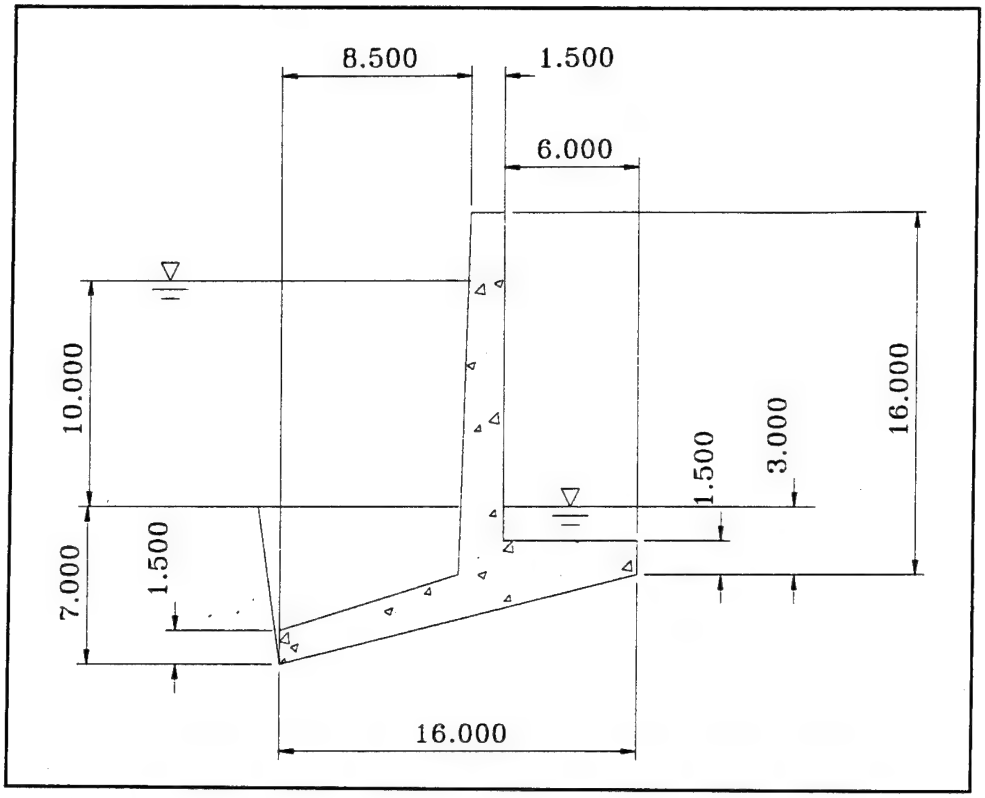


Figure A9. Example problem 9

Discussion of results

There are no differences in the results reported by CTWALL and the EM.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                   Time:  0.29.52
This is example 4 of Appendix N of EM 1110-2-2502
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 9
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation top of stem (ELTS)            =    20.00 ft
  Thickness top of stem (TTS)             =     1.50 ft
  Thickness bottom of stem (TBS)          =     2.00 ft
  Dist. of batter at bot. of stem (TBSR)=      .00 ft
  Depth of heel (THEEL)                   =     1.50 ft
  Depth of heel at stem (STHEEL)          =     2.00 ft
  Elevation of bottom of toe (ELBT)       =     4.00 ft
  Depth of toe (TTOE)                     =     1.50 ft
  Depth of toe at stem (STTOE)            =     3.00 ft
  Width of toe (TWIDTH)                   =     6.00 ft
  Width of base (BWIDTH)                  =    16.00 ft
  Batter of base of structure (BTRB)      =     3.00 ft
  Depth of key (HK)                       =      .00 ft
  Width of bottom of key (TK)             =      .00 ft
  Dist. of batter at bot. of key (BTRK) =      .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00        .00
       .00       1.50
      8.00       4.00
      8.50      20.00
     10.00      20.00
     10.00       5.50
     16.00       5.50
     16.00       4.00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
Driving side soil property data:
                        Moist   Saturated          Elev.
   Phi         c      Unit wt.  unit wt.  Delta    soil
  (deg)      (ksf)     (kcf)     (kcf)    (deg)    (ft)
=======================================================
     .00      .900      .120      .120      .00     7.00
Driving side soil geometry:
  Soil       Batter    Distance
  point     (in:1ft)     (ft)
  =============================
   1           .00    500.00
   2           .00       .00
   3           .00    500.00
Driving side soil profile:
  Soil         x           y
  point       (ft)        (ft)
  =============================
   1      -1491.91        7.00
   2          8.09        7.00
```

```
Resisting side soil property data:
                         Moist    Saturated  Elev.
   Phi         c        Unit wt.   unit wt.   soil     Batter
  (deg)      (ksf)       (kcf)      (kcf)     (ft)    (in:1ft)
========================================================
     .00      .900        .120       .120      7.00      .00
Resisting side soil profile:
  Soil          x           y
  point        (ft)        (ft)
  =============================
   1         10.00        7.00
   2        510.00        7.00
Foundation property data:
  phi for soil-structure interface =       .00 (deg)
  c for soil-structure interface   =      .900 (ksf)
  phi for soil-soil interface      =       .00 (deg)
  c for soil-soil interface        =      .900 (ksf)
Water data:
  Driving side elevation    =    17.00 ft
  Resisting side elevation =      7.00 ft
  Unit weight of water      =    .0625 kcf
  Seepage pressures computed by Line of Creep method.
Minimum required factors of safety:
  Sliding FS    =     1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack *is* down to bottom of heel
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
Resisting side pressures *are not* used in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                              Time:  0.29.52
This is example 4 of Appendix N of EM 1110-2-2502
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 9
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =     .6667
Alpha for the SMF           =     .0000
Calculated earth pressure coefficients:
  Driving side at rest K    =     .0000
  Driving side at rest Kc   =     .0000
  Resisting side at rest K  =     .0000
  Resisting side at rest Kc =     .0000
  No passive pressures used for resisting side.
Depth of cracking =     7.00 ft
Crack extends to bottom of base of structure.
** Driving side pressures **
  Water pressures:
    Elevation    Pressure
      (ft)         (ksf)
    ======================
        17.00       .0000
          .00      1.0625
```

```
** Resisting side pressures **
  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    =====================
        7.00      .0000
        4.00      .2837
         .00     1.0625
** Uplift pressures **
  Water pressures:
     x-coord.   Pressure
       (ft)       (ksf)
    =====================
         .00     1.0625
       16.00      .2837
** Forces and moments **
=========================================================================
             Part            |    Force (kips)     | Mom. Arm  |  Moment |
                             |  Vert.    |  Horiz.|    (ft)   |  (ft-k) |
=========================================================================
Structure:
  Structure weight..........    8.850                  -7.25     -64.15
Structure, driving side:
  Moist soil................     .000                    .00        .00
  Saturated soil............    4.097                 -12.37     -50.69
  Water above structure.....     .000                    .00        .00
  Water above soil..........    5.156                 -11.87     -61.23
  External vertical loads...     .000                    .00        .00
  Ext. horz. pressure loads..              .000          .00        .00
  Ext. horz. line loads......              .000          .00        .00
Structure, resisting side:
  Moist soil................     .000                    .00        .00
  Saturated soil............    1.080                  -3.00      -3.24
  Water above structure.....     .000                    .00        .00
  Water above soil..........     .000                    .00        .00
Driving side:
  Effective earth loads......              .000          .00        .00
  Shear (due to delta).......    .000                    .00        .00
  Horiz. surcharge effects...              .000          .00        .00
  Water loads................             9.031         1.67      15.05
Resisting side:
  Effective earth loads......              .000          .00        .00
  Water loads................            -3.118        -1.92       6.00
Foundation:
  Components of normal.......  -9.310    -2.328        -5.78      55.49
  Components of shear........    .896    -3.586          .00        .00
  Uplift.....................  -10.770                 -9.54     102.77
=========================================================================
** Statics Check **    SUMS =    .000      .000                     .00
Angle of base        =    14.04 degrees
Normal force on base =    9.597 kips
Shear force on base  =    3.696 kips
Max. available shear force =   14.843 kips
Base pressure at heel =    .0603 ksf
Base pressure at toe  =   1.1034 ksf
Xr (measured from toe) =     5.78 ft
Resultant ratio       =    .3506
Stem ratio            =    .3750
Base in compression   =   100.00 %
Overturning ratio     =     1.45
Volume of concrete =     2.19 cubic yds/ft of wall
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Printout of sliding results

```
***********************
**  Sliding Results  **
***********************
Solution converged.  Summation of forces = 0.
           Horizontal   Vertical
  Wedge       Loads       Loads
  Number     (kips)       (kips)
  =================================
     1         .000         .000
     2        9.031        5.156
     3         .000         .000
  Water pressures on wedges:
              Top       Bottom
    Wedge    press.     press.    x-coord.     press.
    number   (ksf)      (ksf)      (ft)        (ksf)
  ===============================================
      1     .0000      .0000
      2                              .0000     1.0625
      2                            16.0000      .2837
      3     .0000      .2837
Points of sliding plane:
  Point 1 (left),  x =      .00 ft,    y =      .00 ft
  Point 2 (right), x =    16.00 ft,    y =     4.00 ft
Depth of cracking =      7.00 ft
Crack extends to bottom of base of structure.
           Failure   Total    Weight    Submerged   Uplift
  Wedge     angle    length  of wedge    length     force
  number    (deg)     (ft)    (kips)      (ft)      (kips)
  =========================================================
     1       .000      .000      .000       .000       .000
     2     14.036    16.492    14.027     16.492     11.101
     3     45.009     4.242      .540      4.242       .602
  Wedge      Net force
  number      (kips)
  ==================
     1          .000
     2        -1.504
     3         1.504
  ==================
     SUM =      .000
+----------------+
| Factor of safety =     5.601  |
+----------------+
```

Example 10

Problem statement

This problem is Example 5N from the EM. The soil geometry is shown in the Figure A10, and the soil properties are shown below:

$$\gamma_{sat} = 0.125 \text{ kcf}$$

$$\phi = 20°$$

$$c = 0.4 \text{ ksf}$$

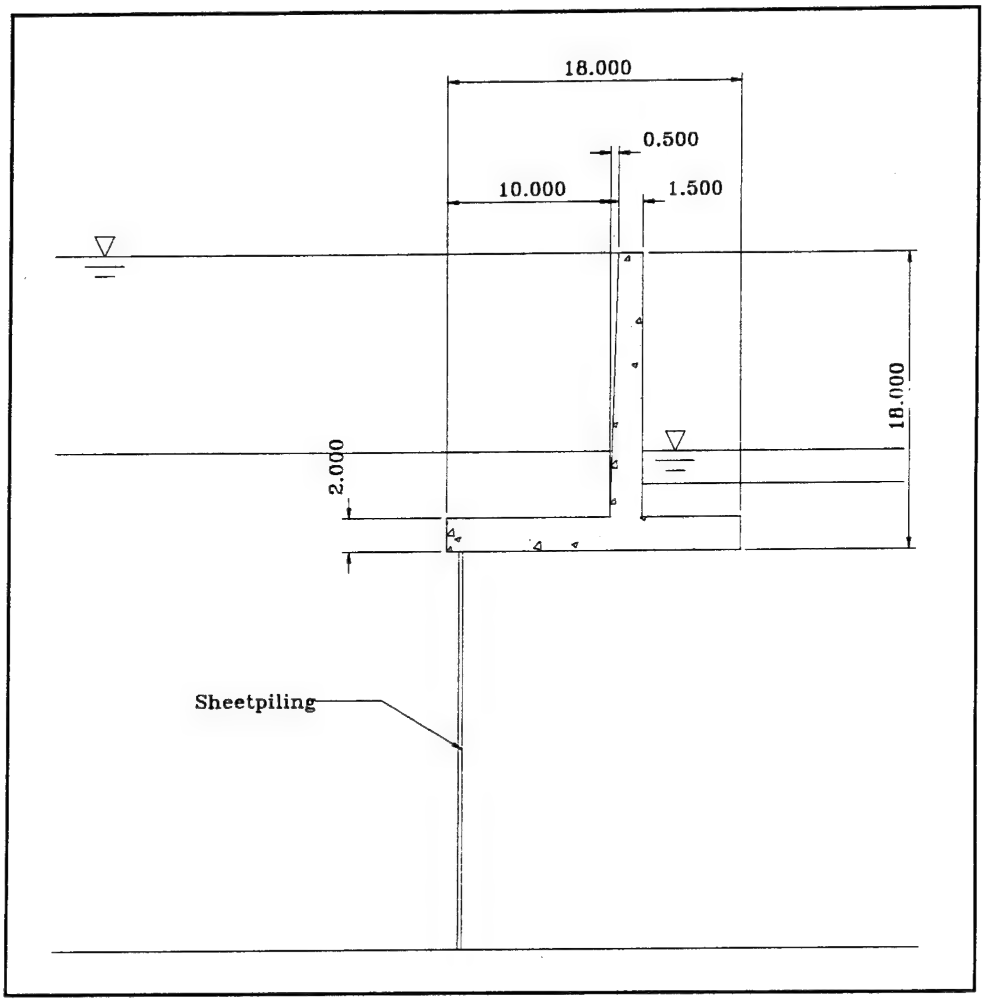


Figure A10. Example problem 10

Discussion of results

There are no differences in the results reported by CTWALL and the EM.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                 Time:  1.15.00
This is example 5 of Appendix N of EM 1110-2-2502
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 10
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)        =    18.00 ft
  Height of stem (HTS)                   =    16.00 ft
  Thickness top of stem (TTS)            =     1.50 ft
  Thickness bottom of stem (TBS)         =     2.00 ft
  Dist. of batter at bot. of stem (TBSR) =      .00 ft
  Depth of heel (THEEL)                  =     2.00 ft
  Distance of batter for heel (BTRH)     =      .00 ft
  Depth of toe (TTOE)                    =     2.00 ft
  Width of toe (TWIDTH)                  =     6.00 ft
  Distance of batter for toe (BTRT)      =      .00 ft
  Width of base (BWIDTH)                 =    18.00 ft
  Depth of key (HK)                      =      .00 ft
  Width of bottom of key (TK)            =      .00 ft
  Dist. of batter at bot. of key (BTRK)  =      .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00       .00
       .00      2.00
     10.00      2.00
     10.50     18.00
     12.00     18.00
     12.00      2.00
     18.00      2.00
     18.00       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
Driving side soil property data:
                          Moist   Saturated          Elev.
   Phi         c       Unit wt.   unit wt.  Delta    soil
  (deg)      (ksf)      (kcf)      (kcf)    (deg)    (ft)
=======================================================
   20.00      .400       .120       .125      .00     6.00
Driving side soil geometry:
  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  =============================
   1          .00     500.00
   2          .00        .00
   3          .00     500.00
```

```
Driving side soil profile:
  Soil        x          y
  point      (ft)       (ft)
  =============================
   1     -1489.88       6.00
   2        10.13       6.00
Resisting side soil property data:
                         Moist   Saturated  Elev.
   Phi         c       Unit wt.  unit wt.   soil     Batter
  (deg)      (ksf)      (kcf)     (kcf)     (ft)    (in:1ft)
=========================================================
   20.00      .400       .120      .125     4.00      .00
Resisting side soil profile:
  Soil        x          y
  point      (ft)       (ft)
  =============================
   1        12.00       4.00
   2       512.00       4.00
Foundation property data:
  phi for soil-structure interface =    20.00 (deg)
  c for soil-structure interface   =     .400 (ksf)
  phi for soil-soil interface      =    20.00 (deg)
  c for soil-soil interface        =     .400 (ksf)
Water data:
  Driving side elevation   =    18.00 ft
  Resisting side elevation =     6.00 ft
  Unit weight of water     =    .0625 kcf
  Input water pressures:
         Distance   Pressure
  Point    (ft)       (ksf)
  ===========================
   1        .00     1.1250
   2        .75     1.1250
   3        .76      .8210
   4      18.00      .5160
Minimum required factors of safety:
  Sliding FS    =    1.33
  Overturning  =   75.00% base in compression
Crack options:
  o  Crack *is* down to bottom of heel
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do not* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                              Time:  1.15.00
This is example 5 of Appendix N of EM 1110-2-2502
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 10
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  0 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF          =    .0000
```

```
Calculated earth pressure coefficients:
  Driving side at rest K    =    .0000
  Driving side at rest Kc   =    .0000
  Resisting side at rest K  =    .6580
  Resisting side at rest Kc =    .8112
  At-rest K's for resisting side calculated.
Depth of cracking =     6.00 ft
Crack extends to bottom of base of structure.
** Driving side pressures **
  Water pressures:
    Elevation    Pressure
      (ft)         (ksf)
    ======================
        18.00       .0000
          .00      1.1250
** Resisting side pressures **
  Water pressures:
    Elevation    Pressure
      (ft)         (ksf)
    ======================
         6.00       .0000
         4.00       .1250
          .00       .5160
  Earth pressures:
    Elevation    Pressure
      (ft)         (ksf)
    ======================
         4.00       .0000
          .00       .0748
** Uplift pressures **
  Water pressures:
     x-coord.    Pressure
       (ft)        (ksf)
    ======================
          .00      1.1250
          .75      1.1250
          .76       .8210
        18.00       .5160
** Forces and moments **
```

Part	Force (kips) Vert.	Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight............	9.600		-8.07	-77.50
Structure, driving side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	5.031		-12.97	-65.25
Water above structure......	.000		.00	.00
Water above soil...........	7.734		-12.84	-99.33
External vertical loads....	.000		.00	.00
Ext. horz. pressure loads..		.000	.00	.00
Ext. horz. line loads......		.000	.00	.00
Structure, resisting side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	1.500		-3.00	-4.50
Water above structure......	.000		.00	.00
Water above soil...........	.750		-3.00	-2.25
Driving side:				
Effective earth loads......		.000	.00	.00
Shear (due to delta).......	.000		.00	.00
Horiz. surcharge effects...		.000	.00	.00
Water loads................		10.125	6.00	60.75
Resisting side:				
Effective earth loads......		-.150	1.33	-.20
Water loads................		-1.407	1.87	-2.63
Foundation:				
Vertical force on base.....	-12.237		-5.64	68.97
Shear on base..............		-8.568	.00	.00
Uplift.....................	-12.378		-9.85	121.94
** Statics Check ** SUMS =	.000	.000		.00

```
Angle of base          =      .00 degrees
Normal force on base =   12.237 kips
Shear force on base  =    8.568 kips
Max. available shear force =    11.217 kips
Base pressure at x=  16.91 ft from toe =    .0000 ksf
Base pressure at toe                   =   1.4475 ksf
Xr (measured from toe) =     5.64 ft
Resultant ratio        =    .3131
Stem ratio             =    .3333
Base in compression    =    93.93 %
Overturning ratio      =     1.38
Volume of concrete =     2.37 cubic yds/ft of wall
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Printout of sliding results

```
***********************
**  Sliding Results  **
***********************
Solution converged.  Summation of forces = 0.
           Horizontal   Vertical
  Wedge      Loads        Loads
  Number    (kips)       (kips)
  ==================================
     1        .000         .000
     2      10.000        8.484
     3        .000         .611
  Water pressures on wedges:
             Top      Bottom
    Wedge   press.   press.   x-coord.     press.
    number  (ksf)    (ksf)     (ft)        (ksf)
  ================================================
      1     .0000    .0000
      2                          .0000     1.1250
      2                          .7500     1.1250
      2                          .7600      .8210
      2                        18.0000      .5160
      3     .1250    .5160
Points of sliding plane:
  Point 1 (left),  x =       .00 ft,    y =      .00 ft
  Point 2 (right), x =     18.00 ft,    y =      .00 ft
Depth of cracking =     6.00 ft
Crack extends to bottom of base of structure.
          Failure   Total    Weight    Submerged   Uplift
  Wedge    angle    length   of wedge   length     force
  number   (deg)     (ft)    (kips)      (ft)      (kips)
  ========================================================
     1      .000      .000      .000      .000       .000
     2      .000    18.000    16.131    18.000     12.378
     3    39.317     6.313     1.221     6.313      2.023
  Wedge     Net force
  number     (kips)
  ===================
     1         .000
     2       -3.777
     3        3.777
  ===================
     SUM =     .000
+----------------+
| Factor of safety =    1.803 |
+----------------+
```

Example 11

Problem statement

This problem is Example 7N from the EM. The soil and structure geometry is shown in Figure A11. The soil properties are shown below:

$$\gamma_{sat} = 0.125 \text{ kcf}$$

$$\phi = 0°$$

$$c = 0.9 \text{ ksf}$$

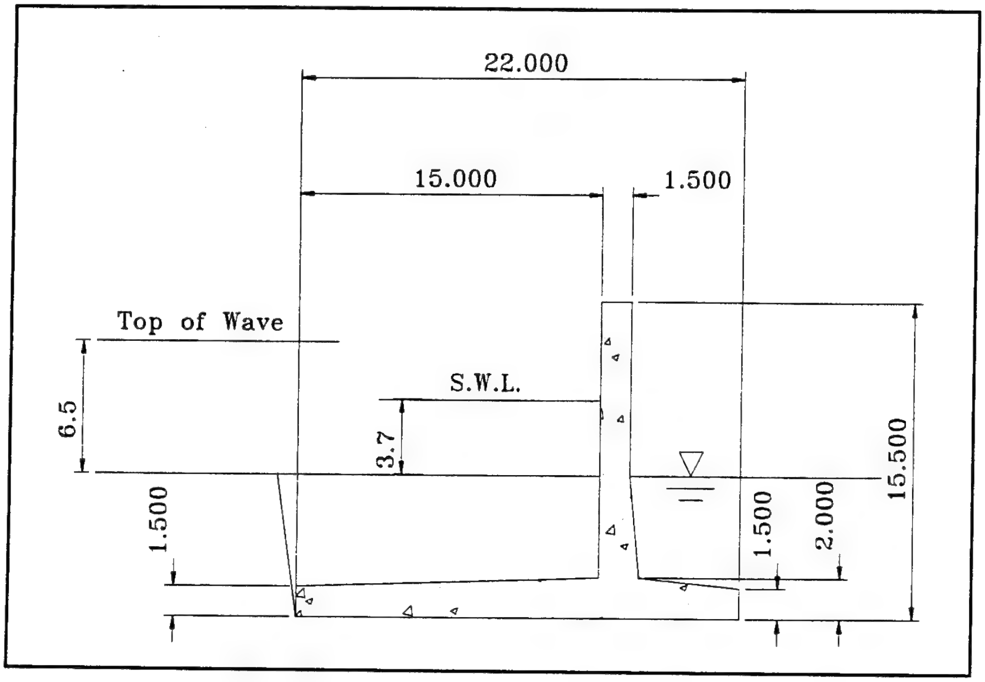


Figure A11. Example problem 11

Discussion of results

The structural wedge weight was assigned a weight and a centroid in the EM example. To make the CTWALL results compare as close as possible, the unit weight of the structure was altered to try and match the weight and centroid value assigned. They could not be made to match exactly. Also, CTWALL cannot model the bend in the stem of the wall.

Echoprint of data

```
****************** Echoprint of Input Data *****************

Date: 93/10/30                                 Time:  0.30.33
This is example 7 of Appendix N of EM 1110-2-2502
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 11
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)       =    15.50 ft
  Height of stem (HTS)                  =    13.50 ft
  Thickness top of stem (TTS)           =     1.50 ft
  Thickness bottom of stem (TBS)        =     2.00 ft
  Dist. of batter at bot. of stem (TBSR)=      .50 ft
  Depth of heel (THEEL)                 =     1.50 ft
  Distance of batter for heel (BTRH)    =      .50 ft
  Depth of toe (TTOE)                   =     1.50 ft
  Width of toe (TWIDTH)                 =     5.00 ft
  Distance of batter for toe (BTRT)     =      .50 ft
  Width of base (BWIDTH)                =    22.00 ft
  Depth of key (HK)                     =      .00 ft
  Width of bottom of key (TK)           =      .00 ft
  Dist. of batter at bot. of key (BTRK) =      .00 ft
Structure coordinates:
   x (ft)    y (ft)
  ==================
       .00       .00
       .00      1.50
     15.00      2.00
     15.00     15.50
     16.50     15.50
     17.00      2.00
     22.00      1.50
     22.00       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .190 kcf
Driving side soil property data:
                         Moist   Saturated          Elev.
   Phi         c       Unit wt.  unit wt.  Delta    soil
  (deg)      (ksf)      (kcf)     (kcf)    (deg)    (ft)
=======================================================
     .00      .900       .120      .125      .00    7.00
Driving side soil geometry:
  Soil       Batter    Distance
  point     (in:1ft)     (ft)
  =============================
  1           .00     500.00
  2           .00        .00
  3           .00     500.00
Driving side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  =============================
  1      -1485.00       7.00
  2         15.00       7.00
Resisting side soil property data:
                         Moist   Saturated  Elev.
   Phi         c       Unit wt.  unit wt.   soil     Batter
  (deg)      (ksf)      (kcf)     (kcf)     (ft)    (in:1ft)
========================================================
     .00      .900       .120      .125     7.00      .00
```

```
Resisting side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  =============================
   1         16.81      7.00
   2        516.81      7.00

Foundation property data:
  phi for soil-structure interface =      .00 (deg)
  c for soil-structure interface   =     .900 (ksf)
  phi for soil-soil interface      =      .00 (deg)
  c for soil-soil interface        =     .900 (ksf)
Water data:
  Driving side elevation    =    10.70 ft
  Resisting side elevation =     7.00 ft
  Unit weight of water      =    .0640 kcf
  Seepage pressures computed by Line of Creep method.
Horizontal line load data:
   Elevation    Force
     (ft)      (kips)
========================
    10.70       5.18
     6.08       2.17
Minimum required factors of safety:
  Sliding FS    =     1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack *is* down to bottom of heel
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                              Time:  0.30.33
This is example 7 of Appendix N of EM 1110-2-2502
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 11
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  5 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF            =    .0000
Calculated earth pressure coefficients:
  Driving side at rest K    =    .0000
  Driving side at rest Kc   =    .0000
  Resisting side at rest K  =   1.0000
  Resisting side at rest Kc =   1.0000
  At-rest K's for resisting side calculated.
Depth of cracking =      7.00 ft
Crack extends to bottom of base of structure.
** Driving side pressures **
  Water pressures:
    Elevation    Pressure
      (ft)        (ksf)
    ======================
```

10.70	.0000
.00	.6848

** Resisting side pressures **

Water pressures:

Elevation (ft)	Pressure (ksf)
7.00	.0000
.00	.5052

Earth pressures:

Elevation (ft)	Pressure (ksf)
7.00	.0000
.00	.3698

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
.00	.6848
6.41	.6848
22.00	.5052

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight...........	11.899		-8.99	-106.92
Structure, driving side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	9.844		-14.62	-143.91
Water above structure......	.000		.00	.00
Water above soil...........	3.552		-14.50	-51.50
External vertical loads....	.000		.00	.00
Ext. horz. pressure loads..		.000	.00	.00
Ext. horz. line loads......		7.344	9.34	68.56
Structure, resisting side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	3.339		-2.51	-8.37
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
Driving side:				
Effective earth loads......		.000	.00	.00
Shear (due to delta).......	.000		.00	.00
Horiz. surcharge effects...		.000	.00	.00
Water loads................		3.664	3.57	13.07
Resisting side:				
Effective earth loads......		-1.294	2.33	-3.02
Water loads................		-1.768	2.33	-4.13
Foundation:				
Vertical force on base.....	-14.968		-5.20	77.77
Shear on base..............		-7.945	.00	.00
Uplift.....................	-13.666		-11.59	158.45
** Statics Check ** SUMS =	.000	.000		.00

Angle of base = .00 degrees
Normal force on base = 14.968 kips
Shear force on base = 7.945 kips
Max. available shear force = 14.028 kips
Base pressure at x= 15.59 ft from toe = .0000 ksf
Base pressure at toe = 1.9206 ksf
Xr (measured from toe) = 5.20 ft
Resultant ratio = .2362
Stem ratio = .2273
Base in compression = 70.85 %
Overturning ratio = 1.32
Volume of concrete = 2.32 cubic yds/ft of wall
NOTE: The engineer shall verify that the computed bearing pressures below the wall do not exceed the

allowable foundation bearing pressure, or, perform a bearing capacity analysis using the program CBEAR. Also, the engineer shall verify that the base pressures do not result in excessive differential settlement of the wall foundation.

Printout of sliding results

```
***********************
**  Sliding Results  **
***********************
Solution converged.  Summation of forces = 0.
           Horizontal   Vertical
  Wedge       Loads       Loads
  Number     (kips)      (kips)
  ==================================
     1         .000        .000
     2       11.008       3.552
     3         .000        .000
  Water pressures on wedges:
               Top      Bottom
    Wedge     press.    press.   x-coord.     press.
    number    (ksf)     (ksf)     (ft)        (ksf)
  ================================================
      1      .0000     .0000
      2                            .0000      .6848
      2                           6.4126      .6848
      2                          22.0000      .5052
      3      .0000     .5052
Points of sliding plane:
  Point 1 (left),  x =      .00 ft,   y =      .00 ft
  Point 2 (right), x =    22.00 ft,   y =      .00 ft
Depth of cracking =     7.00 ft
Crack extends to bottom of base of structure.
           Failure    Total    Weight    Submerged    Uplift
  Wedge     angle    length   of wedge    length      force
  number    (deg)     (ft)     (kips)      (ft)      (kips)
  =========================================================
     1       .000      .000      .000       .000       .000
     2       .000    22.000    25.082     22.000     13.666
     3     45.036     9.893     3.059      9.893      2.499
  Wedge      Net force
  number      (kips)
  ===================
     1          .000
     2        -6.822
     3         6.822
  ===================
     SUM =      .000
+----------------+
| Factor of safety =    3.351 |
+----------------+
```

Example 12

Problem statement

This problem is Example 1 from Enclosure 4 of the ETL. The soil and structure geometry are shown in Figure A12. The soil properties are shown below:

$$\gamma = 0.120 \text{ kcf}$$

$$\phi = 30°$$

$$c = 0 \text{ ksf}$$

$$SMF = 2/3$$

$$\delta = 10.5°$$

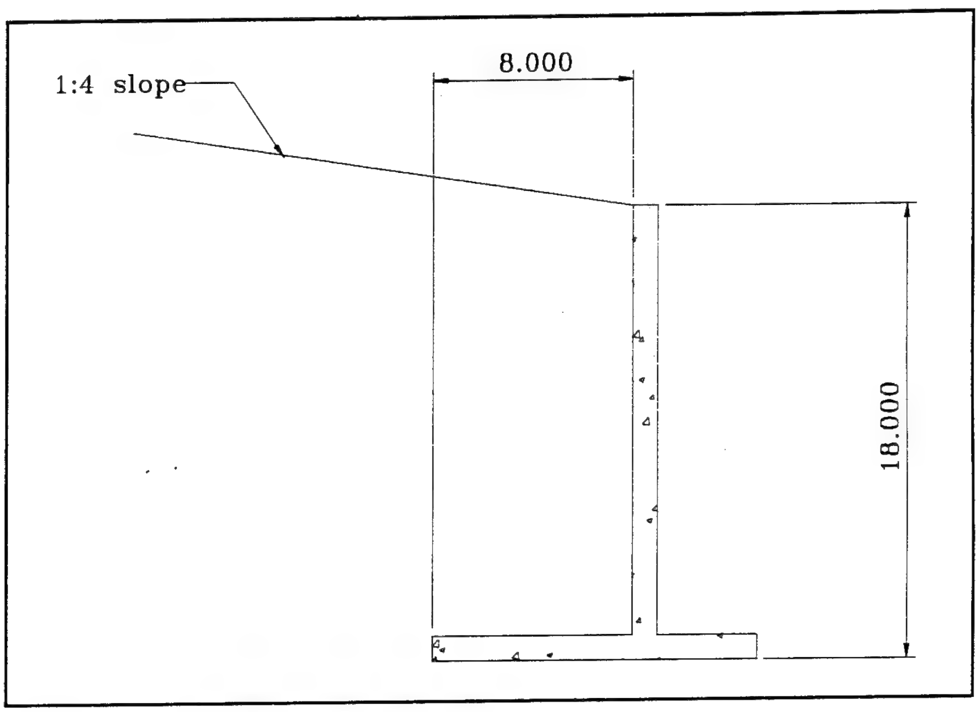


Figure A12. Example problem 12

Discussion of results

The ETL and CTWALL results compare exactly. Only the overturning results are of interest for this problem.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                 Time:  0.30.56
This is example 1, enclosure 4 of ETL 1110-2-322
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 12
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)         =     18.00 ft
  Height of stem (HTS)                    =     16.00 ft
  Thickness top of stem (TTS)             =      2.00 ft
  Thickness bottom of stem (TBS)          =      2.00 ft
  Dist. of batter at bot. of stem (TBSR)=         .00 ft
  Depth of heel (THEEL)                   =      2.00 ft
  Distance of batter for heel (BTRH)      =       .00 ft
  Depth of toe (TTOE)                     =      2.00 ft
  Width of toe (TWIDTH)                   =      6.00 ft
  Distance of batter for toe (BTRT)       =       .00 ft
  Width of base (BWIDTH)                  =     16.00 ft
  Depth of key (HK)                       =       .00 ft
  Width of bottom of key (TK)             =       .00 ft
  Dist. of batter at bot. of key (BTRK) =         .00 ft
Structure coordinates:
   x (ft)    y (ft)
  ==================
      .00       .00
      .00      2.00
     8.00      2.00
     8.00     18.00
    10.00     18.00
    10.00      2.00
    16.00      2.00
    16.00       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =      .150 kcf
Driving side soil property data:
                          Moist    Saturated           Elev.
   Phi          c       Unit wt.   unit wt.   Delta    soil
  (deg)       (ksf)      (kcf)      (kcf)     (deg)    (ft)
=======================================================
   30.00       .000       .120       .120     10.50    18.00
Driving side soil geometry:
  Soil        Batter     Distance
  point      (in:1ft)      (ft)
  ============================
  1          3.00     500.00
  2           .00        .00
  3           .00     500.00
Driving side soil profile:
  Soil          x            y
  point        (ft)         (ft)
  ============================
  1      -1492.00     143.00
  2       -492.00     143.00
  3          8.00      18.00
```

```
Resisting side soil property data:
                           Moist   Saturated  Elev.
   Phi          c        Unit wt.  unit wt.   soil     Batter
  (deg)       (ksf)       (kcf)     (kcf)     (ft)    (in:1ft)
========================================================
   30.00       .000        .120      .120      2.00      .00
Resisting side soil profile:
  Soil          x           y
  point        (ft)        (ft)
  =============================
   1          16.00       2.00
   2         516.00       2.00
Foundation property data:
  phi for soil-structure interface =    30.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    30.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation    =   -10.00 ft
  Resisting side elevation =   -10.00 ft
  Unit weight of water      =    .0624 kcf
  Seepage pressures computed are hydrostatic.
Minimum required factors of safety:
  Sliding FS    =    1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =    .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of overturning results

```
********************** Output Results **********************

Date: 93/10/30                                  Time:  0.30.56
This is example 1, enclosure 4 of ETL 1110-2-322
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 12
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =    .6667
Alpha for the SMF          = -42.1816
Calculated earth pressure coefficients:
  Driving side at rest K     =    .3980
  Driving side at rest Kc    =    .9601
  Resisting side at rest K  =    .5000
  Resisting side at rest Kc =    .7071
  At-rest K's for resisting side calculated.
Depth of cracking =       .00 ft
** Driving side pressures **
  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        20.00       .0000
          .00      1.3191
```

** Resisting side pressures **

Earth pressures:

Elevation (ft)	Pressure (ksf)
2.00	.0000
.00	.1200

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
.00	.0000
16.00	.0000

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight...........	9.600		-7.50	-72.00
Structure, driving side:				
Moist soil.................	16.320		-12.08	-197.12
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
External vertical loads....	.000		.00	.00
Ext. horz. pressure loads..		.000	.00	.00
Ext. horz. line loads......		.000	.00	.00
Structure, resisting side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
Driving side:				
Effective earth loads......		13.191	6.67	87.94
Shear (due to delta).......	2.445		-16.00	-39.12
Horiz. surcharge effects...		.000	.00	.00
Water loads................		.000	.00	.00
Resisting side:				
Effective earth loads......		-.120	.67	-.08
Water loads................		.000	.00	.00
Foundation:				
Vertical force on base.....	-28.365		-7.77	220.38
Shear on base..............		-13.071	.00	.00
Uplift.....................	.000		.00	.00
** Statics Check ** SUMS =	.000	.000		.00

```
Angle of base          =       .00 degrees
Normal force on base =   28.365 kips
Shear force on base  =   13.071 kips
Max. available shear force =   16.376 kips
Base pressure at heel =   1.6195 ksf
Base pressure at toe  =   1.9261 ksf
Xr (measured from toe) =     7.77 ft
Resultant ratio         =    .4856
Stem ratio              =    .3750
Base in compression     =   100.00 %
Overturning ratio       =     3.51
Volume of concrete =      2.37 cubic yds/ft of wall
```

NOTE: The engineer shall verify that the computed bearing pressures below the wall do not exceed the allowable foundation bearing pressure, or, perform a bearing capacity analysis using the program CBEAR. Also, the engineer shall verify that the base pressures do not result in excessive differential settlement of the wall foundation.

Example 13

Problem statement

This problem is example 2 from enclosure 4 of the ETL. The soil and structure geometry is shown in Figure A13. The soil properties are given below:

Backfill:

$$\gamma_{moist} = 0.120 \text{ kcf}$$
$$\gamma_{sat} = 0.125 \text{ kcf}$$
$$\phi = 35°$$
$$c = 0 \text{ ksf}$$
$$SMF = 2/3$$
$$\delta = 12.5°$$

Foundation:

$$\phi = 35°$$
$$c = 0 \text{ ksf}$$

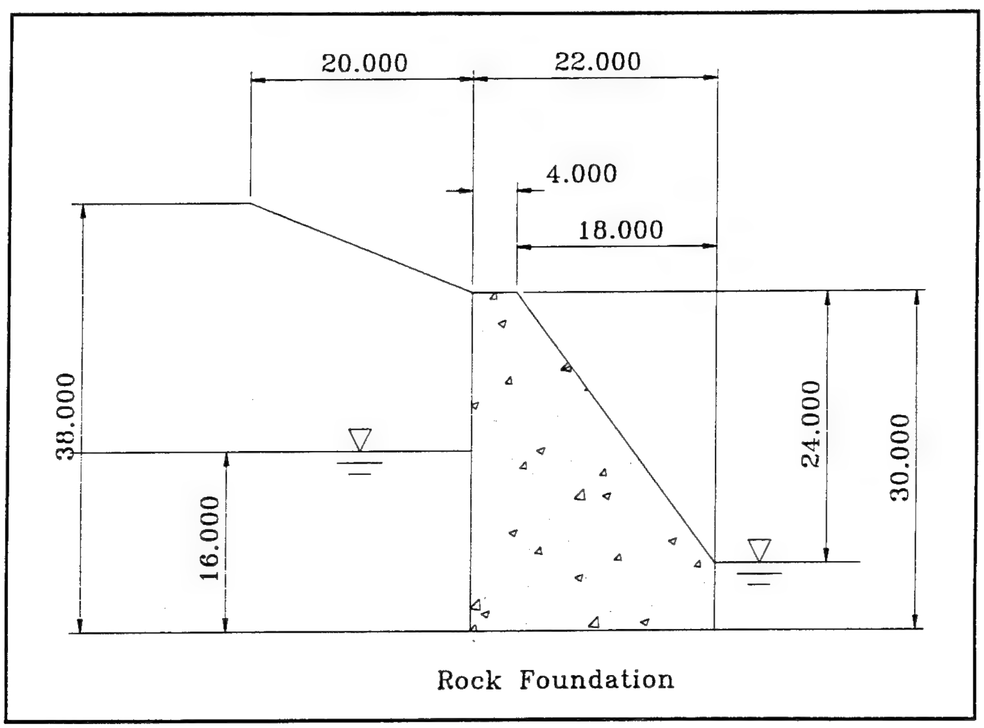


Figure A13. Example problem 13

Discussion of results

The results from CTWALL compare exactly with the results from the ETL. Only the overturning results are of interest for this problem.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                   Time:  0.31.19
This is example 2, enclosure 4 from ETL 1110-2-322
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 13
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)          =    30.00 ft
  Height of stem (HTS)                     =    24.00 ft
  Thickness top of stem (TTS)              =     4.00 ft
  Thickness bottom of stem (TBS)           =    22.00 ft
  Dist. of batter at bot. of stem (TBSR)=       18.00 ft
  Depth of heel (THEEL)                    =     6.00 ft
  Distance of batter for heel (BTRH)       =      .00 ft
  Depth of toe (TTOE)                      =     6.00 ft
  Width of toe (TWIDTH)                    =      .00 ft
  Distance of batter for toe (BTRT)        =      .00 ft
  Width of base (BWIDTH)                   =    22.00 ft
  Depth of key (HK)                        =      .00 ft
  Width of bottom of key (TK)              =      .00 ft
  Dist. of batter at bot. of key (BTRK) =         .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00        .00
       .00      30.00
      4.00      30.00
     22.00       6.00
     22.00        .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =      .150 kcf
Driving side soil property data:
                              Moist   Saturated             Elev.
   Phi          c           Unit wt.   unit wt.   Delta     soil
  (deg)       (ksf)          (kcf)      (kcf)     (deg)     (ft)
=======================================================
   35.00       .000          .120       .125      12.50     30.00
Driving side soil geometry:
  Soil       Batter      Distance
  point     (in:1ft)       (ft)
  ============================
   1          4.80        20.00
   2           .00       500.00
   3           .00       500.00
```

```
Driving side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  ============================
   1     -1520.00      38.00
   2       -20.00      38.00
   3          .00      30.00
Resisting side soil property data:
                         Moist   Saturated  Elev.
   Phi         c       Unit wt.  unit wt.  soil     Batter
  (deg)      (ksf)      (kcf)     (kcf)    (ft)    (in:1ft)
=======================================================
   35.00      .000       .120      .125     6.00      .00
Resisting side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  ============================
   1        22.00       6.00
   2       522.00       6.00
Foundation property data:
  phi for soil-structure interface =     45.00 (deg)
  c for soil-structure interface   =      .000 (ksf)
  phi for soil-soil interface      =     45.00 (deg)
  c for soil-soil interface        =      .000 (ksf)
Water data:
  Driving side elevation    =    16.00 ft
  Resisting side elevation =      6.00 ft
  Unit weight of water      =    .0625 kcf
  Input water pressures:
         Distance   Pressure
  Point    (ft)       (ksf)
  ==========================
   1        .00      1.0000
   2      22.00       .3750
Minimum required factors of safety:
  Sliding FS    =     1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of the overturning results

```
********************** Output Results **********************

Date: 93/10/30                               Time:  0.31.19
This is example 2, enclosure 4 from ETL 1110-2-322
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 13
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
***************************
**  Overturning Results  **
***************************
Solution converged in  1 iterations.
SMF used to calculate K's =     .6667
Alpha for the SMF          = -49.2964
Calculated earth pressure coefficients:
  Driving side at rest K    =    .3527
```

```
   Driving side at rest Kc   =    .9087
   Resisting side at rest K  =    .4264
   Resisting side at rest Kc =    .6530
   At-rest K's for resisting side calculated.
 Depth of cracking =      .00 ft
 ** Driving side pressures **
   Water pressures:
     Elevation   Pressure
       (ft)        (ksf)
     ======================
         16.00      .0000
           .00     1.0000
   Earth pressures:
     Elevation   Pressure
       (ft)        (ksf)
     ======================
         30.00      .0000
         16.00      .9033
         14.75      .9648
           .00     1.3639
 ** Resisting side pressures **
   Water pressures:
     Elevation   Pressure
       (ft)        (ksf)
     ======================
          6.00      .0000
           .00      .3750
   Earth pressures:
     Elevation   Pressure
       (ft)        (ksf)
     ======================
          6.00      .0000
           .00      .1236
 ** Uplift pressures **
   Water pressures:
      x-coord.   Pressure
       (ft)        (ksf)
     ======================
           .00     1.0000
         22.00      .3750
 ** Forces and moments **
```

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight...........	66.600		-13.43	-894.60
Structure, driving side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
External vertical loads....	.000		.00	.00
Ext. horz. pressure loads..		.000	.00	.00
Ext. horz. line loads......		.000	.00	.00
Structure, resisting side:				
Moist soil.................	.000		.00	.00
Saturated soil.............	.000		.00	.00
Water above structure......	.000		.00	.00
Water above soil...........	.000		.00	.00
Driving side:				
Effective earth loads......		24.665	10.87	268.05
Shear (due to delta).......	5.468		-22.00	-120.30
Horiz. surcharge effects...		.000	.00	.00
Water loads................		8.000	5.33	42.67
Resisting side:				
Effective earth loads......		-.371	2.00	-.74
Water loads................		-1.125	2.00	-2.25

```
Foundation:
  Vertical force on base.....  -56.943                          -9.05    515.59
  Shear on base.............              -31.169                 .00       .00
  Uplift....................  -15.125                          -12.67    191.58
==========================================================================
** Statics Check **   SUMS =       .000        .000                         .00
Angle of base        =      .00 degrees
Normal force on base =   56.943 kips
Shear force on base  =   31.169 kips
Max. available shear force =   56.943 kips
Base pressure at heel =   1.2150 ksf
Base pressure at toe  =   3.9617 ksf
Xr (measured from toe) =     9.05 ft
Resultant ratio        =    .4116
Stem ratio             =    .0000
Base in compression    =   100.00 %
Overturning ratio      =     2.03
Volume of concrete =    16.44 cubic yds/ft of wall
NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.
```

Example 14

Problem statement

This problem is taken from the CSLIDE user's manual, Example 1A, in Appendix A. The soil and structure geometry is shown in Figure A14. The soil properties are given below:

Backfill:

$$\gamma_{sat} = 0.120 \text{ kcf}$$

$$\phi = 28°$$

$$c = 0 \text{ ksf}$$

Foundation:

$$\phi = 30°$$

$$c = 0 \text{ ksf}$$

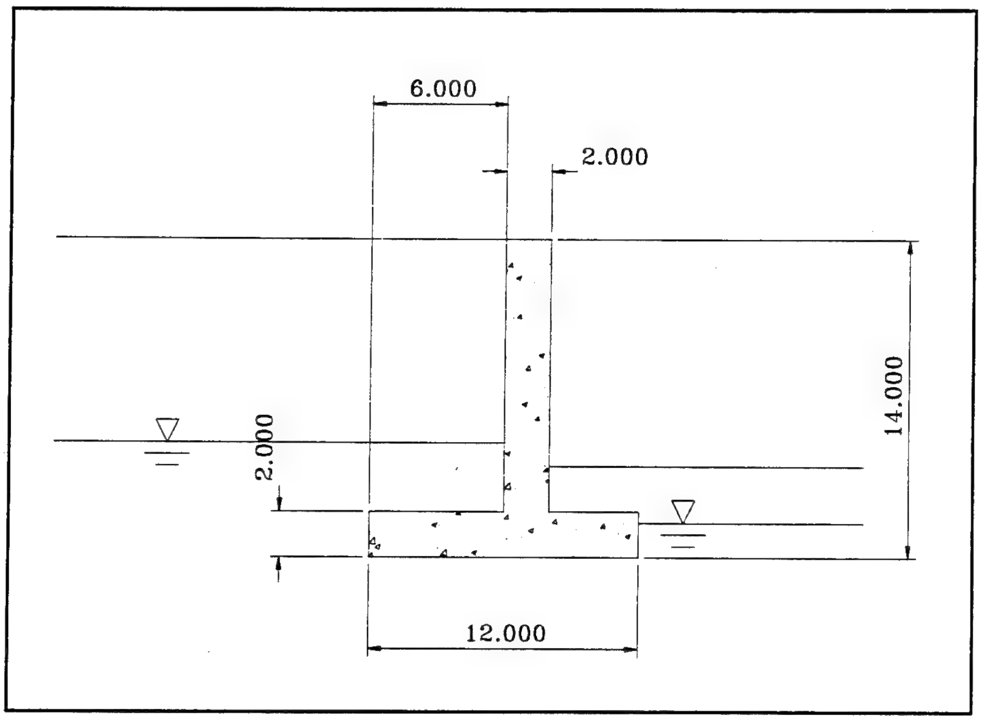


Figure A14. Example problem 14

Discussion of results

Only the sliding results are of interest, and these results compare exactly with CSLIDE.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                Time:  0.31.55
This is example 1a of Appendix A of the CSLIDE user's guide
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 14
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)        =    14.00 ft
  Height of stem (HTS)                   =    12.00 ft
  Thickness top of stem (TTS)            =     2.00 ft
  Thickness bottom of stem (TBS)         =     2.00 ft
  Dist. of batter at bot. of stem (TBSR) =      .00 ft
  Depth of heel (THEEL)                  =     2.00 ft
  Distance of batter for heel (BTRH)     =      .00 ft
  Depth of toe (TTOE)                    =     2.00 ft
  Width of toe (TWIDTH)                  =     4.00 ft
  Distance of batter for toe (BTRT)      =      .00 ft
  Width of base (BWIDTH)                 =    12.00 ft
  Depth of key (HK)                      =      .00 ft
  Width of bottom of key (TK)            =      .00 ft
  Dist. of batter at bot. of key (BTRK)  =      .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00       .00
       .00      2.00
      6.00      2.00
      6.00     14.00
      8.00     14.00
      8.00      2.00
     12.00      2.00
     12.00       .00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =     .150 kcf
Driving side soil property data:
                       Moist   Saturated          Elev.
   Phi         c      Unit wt.  unit wt.  Delta   soil
  (deg)      (ksf)     (kcf)     (kcf)    (deg)   (ft)
=====================================================
  28.00      .000      .120      .120      .00   14.00
Driving side soil geometry:
 Soil      Batter    Distance
 point    (in:1ft)     (ft)
 ============================
   1          .00    500.00
   2          .00       .00
   3          .00    500.00
```

```
Driving side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  ============================
   1      -1494.00     14.00
   2          6.00     14.00
Resisting side soil property data:
                       Moist   Saturated  Elev.
   Phi         c     Unit wt.  unit wt.  soil     Batter
  (deg)      (ksf)    (kcf)     (kcf)     (ft)   (in:1ft)
========================================================
  28.00      .000      .120      .120     4.00      .00
Resisting side soil profile:
  Soil         x          y
  point       (ft)       (ft)
  ============================
   1          8.00      4.00
   2        508.00      4.00
Foundation property data:
  phi for soil-structure interface =    30.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    30.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation    =     5.00 ft
  Resisting side elevation =     1.50 ft
  Unit weight of water      =    .0624 kcf
  Seepage pressures computed by Line of Creep method.
Minimum required factors of safety:
  Sliding FS    =    1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of the sliding results

```
***********************
**  Sliding Results  **
***********************
Solution converged.  Summation of forces = 0.
           Horizontal    Vertical
  Wedge       Loads        Loads
  Number     (kips)       (kips)
  ==================================
     1         .000         .000
     2         .000         .000
     3         .000         .000
  Water pressures on wedges:
              Top      Bottom
    Wedge    press.    press.   x-coord.     press.
    number   (ksf)     (ksf)      (ft)       (ksf)
  ================================================
      1     .0000      .2530
      2                           .0000       .2530
      2                         12.0000       .1113
      3     .0000      .1113
Points of sliding plane:
  Point 1 (left),  x =      .00 ft,   y =      .00 ft
  Point 2 (right), x =    12.00 ft,   y =      .00 ft
```

Depth of cracking = .00 ft

Wedge number	Failure angle (deg)	Total length (ft)	Weight of wedge (kips)	Submerged length (ft)	Uplift force (kips)
1	-53.680	17.376	8.645	6.206	.785
2	.000	12.000	16.800	12.000	2.186
3	36.355	6.748	1.304	2.530	.141

Wedge number	Net force (kips)
1	-6.653
2	4.950
3	1.703
SUM =	.000

| Factor of safety = 1.705 |

Example 15

Problem statement

This problem is Example 2 from Appendix B of the CSLIDE user's manual. The soil and structure geometry are shown in Figure A15. The soil properties are given below:

$$\gamma_{sat} = 0.132 \text{ kcf}$$

$$\phi = 36°$$

$$c = 0 \text{ ksf}$$

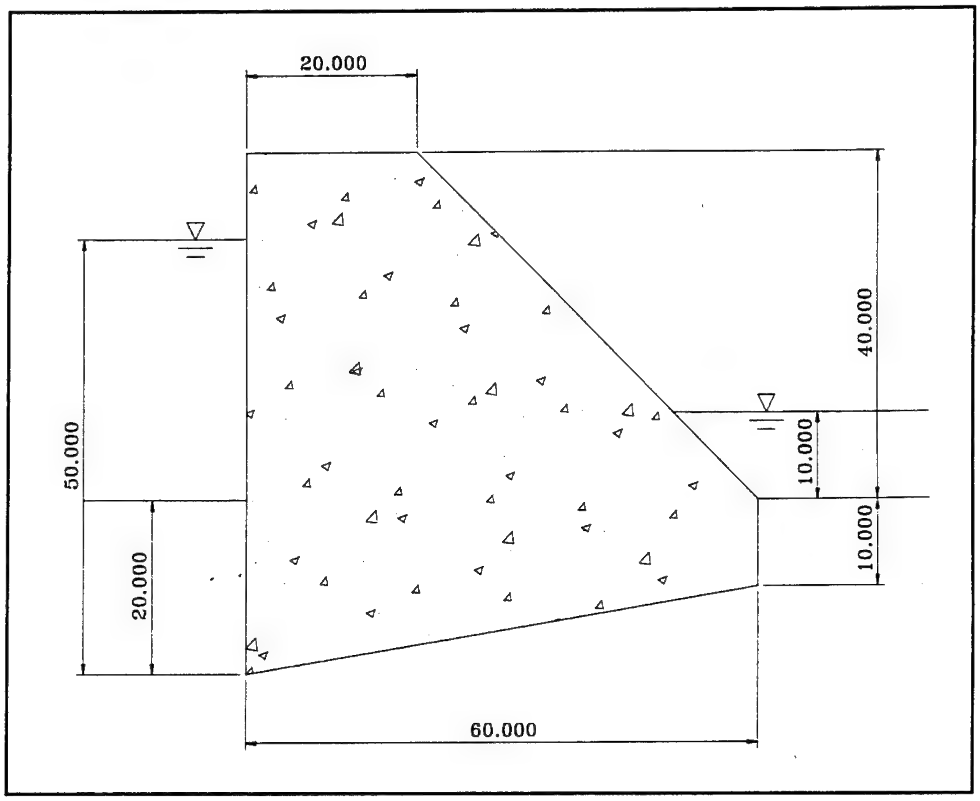


Figure A15. Example problem 15

Discussion of results

Only the sliding results are of interest, and they compare exactly with the CSLIDE results.

Echoprint of data

```
****************** Echoprint of Input Data ******************

Date: 93/10/30                                  Time:  0.32.18
This is example 2 of Appendix B of the CSLIDE user's guide
Company name:
  U.S. Army Corps of Engineers - Waterways Experiment Station
Project name:
  User's Guide to CTWALL - Example 15
Project location:
  Vicksburg, MS
Wall location:

Computed by: mep
Structural geometry data:
  Elevation of top of stem (ELTS)        =     90.00 ft
  Height of stem (HTS)                   =     40.00 ft
  Thickness top of stem (TTS)            =     20.00 ft
  Thickness bottom of stem (TBS)         =     60.00 ft
  Dist. of batter at bot. of stem (TBSR) =     40.00 ft
  Depth of heel (THEEL)                  =     20.00 ft
  Distance of batter for heel (BTRH)     =       .00 ft
  Depth of toe (TTOE)                    =     10.00 ft
  Width of toe (TWIDTH)                  =       .00 ft
  Distance of batter for toe (BTRT)      =       .00 ft
  Width of base (BWIDTH)                 =     60.00 ft
  Depth of key (HK)                      =       .00 ft
  Width of bottom of key (TK)            =       .00 ft
  Dist. of batter at bot. of key (BTRK)  =       .00 ft
Structure coordinates:
   x (ft)     y (ft)
  ==================
       .00     30.00
       .00     90.00
     20.00     90.00
     60.00     50.00
     60.00     40.00
NOTE: X=0 is located at the left-hand side
      of the structure.  The Y values correspond
      to the actual elevation used.
Structural property data:
  Unit weight of concrete =      .150 kcf
Driving side soil property data:
                          Moist   Saturated           Elev.
   Phi          c       Unit wt.  unit wt.   Delta    soil
  (deg)       (ksf)      (kcf)     (kcf)     (deg)    (ft)
=========================================================
   36.00       .000       .120      .132       .00    50.00
Driving side soil geometry:
  Soil       Batter    Distance
  point     (in:1ft)     (ft)
  =============================
   1           .00     500.00
   2           .00        .00
   3           .00     500.00
Driving side soil profile:
  Soil          x           y
  point       (ft)        (ft)
  =============================
   1      -1500.00       50.00
   2           .00       50.00
Resisting side soil property data:
                          Moist   Saturated  Elev.
   Phi          c       Unit wt.  unit wt.   soil    Batter
  (deg)       (ksf)      (kcf)     (kcf)     (ft)   (in:1ft)
=========================================================
   36.00       .000       .120      .132     50.00      .00
```

```
Resisting side soil profile:
  Soil         x          y
  point      (ft)       (ft)
  ============================
   1        60.00      50.00
   2       560.00      50.00
Foundation property data:
  phi for soil-structure interface =    24.00 (deg)
  c for soil-structure interface   =     .000 (ksf)
  phi for soil-soil interface      =    36.00 (deg)
  c for soil-soil interface        =     .000 (ksf)
Water data:
  Driving side elevation   =    80.00 ft
  Resisting side elevation =    60.00 ft
  Unit weight of water     =    .0625 kcf
  Seepage pressures computed by Line of Creep method.
Minimum required factors of safety:
  Sliding FS    =     1.50
  Overturning  =  100.00% base in compression
Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water
Strength mobilization factor =     .6667
At-rest pressures on the resisting side *are used*
in the overturning analysis.
Forces on the resisting side *are used* in the sliding analysis.
*Do* iterate in overturning analysis.
```

Printout of the sliding results

```
***********************
**  Sliding Results  **
***********************
Solution converged.  Summation of forces = 0.
           Horizontal    Vertical
  Wedge       Loads        Loads
  Number     (kips)        (kips)
  =================================
     1          .000       35.062
     2        25.000        3.125
     3          .000        6.621
  Water pressures on wedges:
              Top       Bottom
    Wedge    press.     press.    x-coord.     press.
    number   (ksf)      (ksf)      (ft)        (ksf)
  ===============================================
      1     1.8750     2.8498
      2                              .0000      2.8498
      2                            60.0000      1.3876
      3      .6250     1.3876
Points of sliding plane:
  Point 1 (left),  x =      .00 ft,    y =     30.00 ft
  Point 2 (right), x =    60.00 ft,    y =     40.00 ft
Depth of cracking =      .00 ft
           Failure    Total     Weight     Submerged    Uplift
  Wedge     angle     length   of wedge     length      force
  number    (deg)      (ft)     (kips)       (ft)       (kips)
  =======================================================
     1    -46.924    27.380     24.684     27.380      64.683
     2      9.462    60.828    375.000     60.828     128.875
     3     43.350    14.568      6.991     14.568      14.659
  Wedge      Net force
  number      (kips)
  ==================
     1       -61.831
     2        48.586
     3        13.245
  ==================
    SUM =      .000
```

```
+-----------------+
| Factor of safety =   10.946 |
+-----------------+
```

Appendix B
Program Customization

Available Options

CTWALL has various options which may be configured to the user's needs.

Definition of Options

These items are shown in Figure B1 and are explained below:

a. **Display type**. CTWALL automatically sets itself up to run in the highest resolution that the user's machine can support. The graphics modes available are VGA, EGA, and CGA. The user can use this option to alter which graphics mode CTWALL starts up in.

b. **Color**. CTWALL automatically uses color if possible. The user may set CTWALL for a monochrome display is desired.

c. **Printer type**. The user is allowed to configure the graphics output for a particular printers. A list of printers is presented from which the user can select. The list is quite extensive, but if a particular printer is not shown, a printer should be chosen that is similar to the desired printer. Many printers emulate an epson printer so this could also be an option if your particular printer is not shown.

d. **Printer connection**. This option deals with the method by which information is sent to the printer. The default is HARDWARE which is good in most cases and results in the fastest print times. BIOS may not be good for networked printers and has the next fastest print time. STREAM is good for networked printers but has the slowest print time. The user should try HARDWARE first, and if this does not work, select one of the other methods.

e. **Printer resolution**. The selections are low, medium, and high resolution. The actual resolution is printer dependent. The higher the resolution, the longer the print time.

f. **Page layout**. The user can select a portrait or landscape layout.

g. **Default filenames**. The user is allowed to select directories where the data files, output files, and save files are stored. This option lets the user segment the files based on projects.

h. **Default structural screen**. The user can select which structural screen is the default for entering structural geometry. The two different options are shown in Figures 4 and 5 in Chapter 4 of the main text of this report.

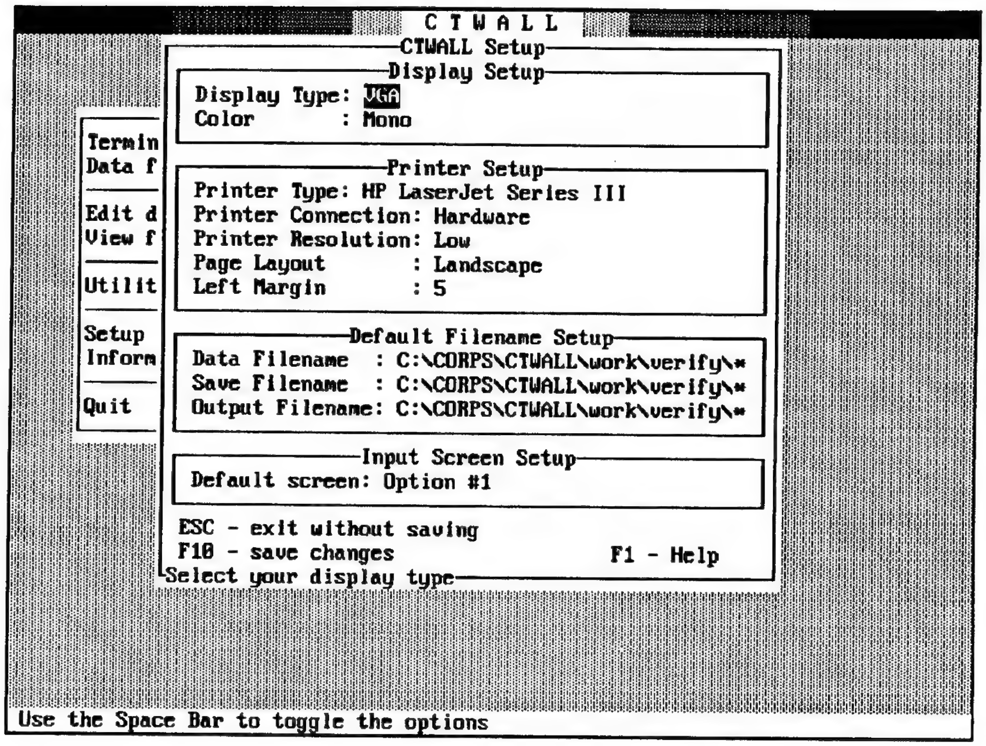


Figure B1. Setup screen

Appendix C
Text Editor

Operation of Text Editor

CTWALL has a built in text editor that can be used to edit small files of no more than 4,000 characters long. This is sufficient to edit the data files that CTWALL uses. The commands available in the text editor are shown in Figure C1.

Steps in File Editing

The process for editing a file is:

a. Select 'Edit File' from the main menu. A file selection box will appear.

b. Change to the directory containing your file.

c. Select the file to be edited.

d. Edit the file.

e. Press the **ESC** key. A confirmation box with the filename will appear.

f. Confirm the name that the file is to be saved under and press the **ENTER** key.

g. The file is saved.

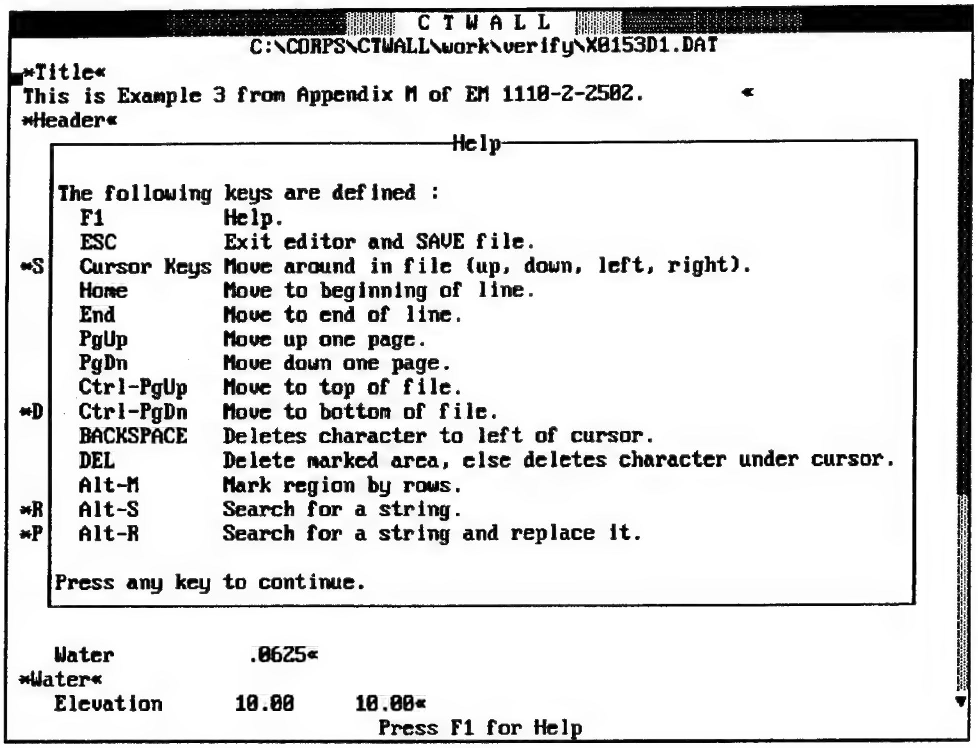


Figure C1. Text editor

Appendix D
Utility Equations

Content of Utility Equations

CTWALL has several utility equations built in to allow the user to perform checks of hand calculations and simple parametric studies. The equations incorporated into this utility function come from EM 1110-2-2502 and ETL 1110-2-322.[1] The equations pertain to the calculation of critical failure angles of wedges, earth pressure coefficients, and earth pressure forces. Equations for both the driving and resisting wedges are provided. The main utility equation menu is shown in Figure D1. An example of the critical failure angle screen for the driving side is shown in Figure D2.

Operation of Utility Equations

The operation of the utility equations is fairly simple. The user can receive help by pressing **<F1>**. The equations used are referenced at the top of each utility screen. The user can use any equation in any order, but there are some advantages if a top-down order is followed as shown in Figure D1. When the critical angle is calculated, a length and weight of a wedge is calculated using the slope of the backfill and height of the wedge entered. These values are fed to the equation for the earth pressure force, thereby relieving the user of calculating these values by hand.

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1 References are given on page 1 of the main text.

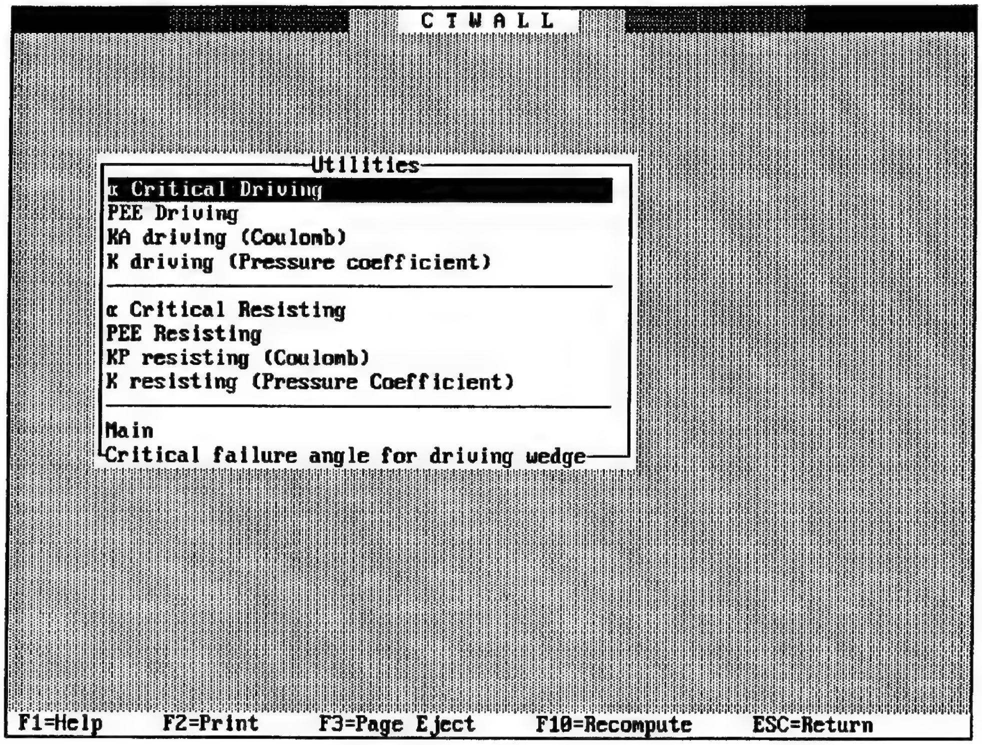

Figure D1. Main utility equation menu

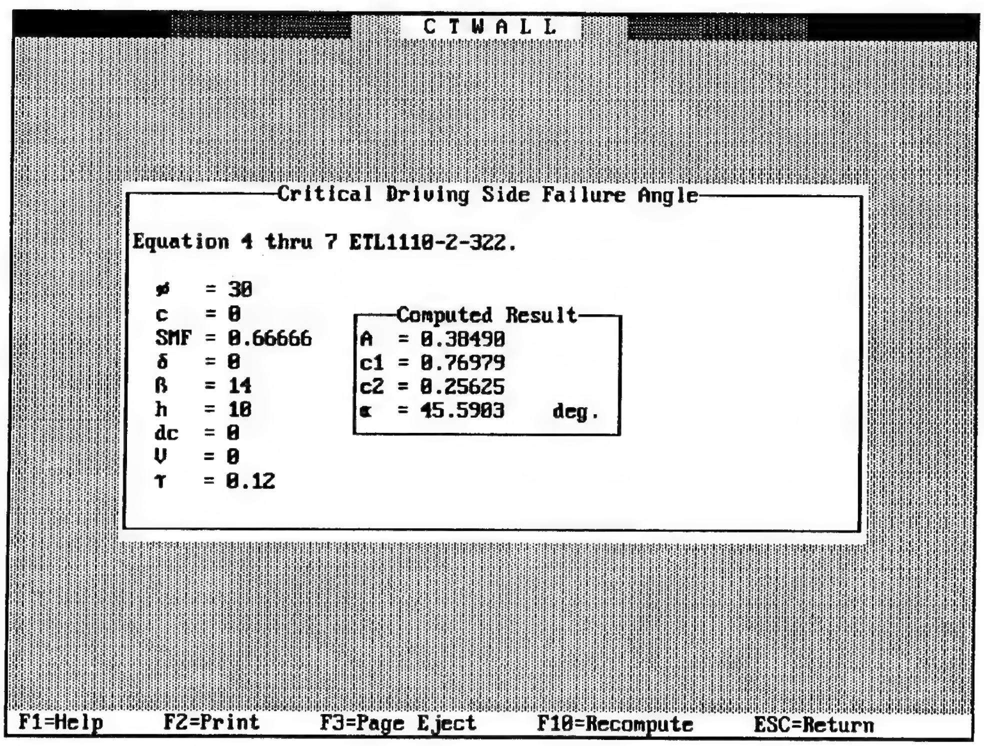

Figure D2. Critical failure angle menu for driving side

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13. ABSTRACT *(Maximum 200 words)*

CTWALL is a computer program that assesses the stability of T-type retaining and flood walls. The purpose of the program is to assess these structures in accordance with EM 1110-2-2502 and ETL 1110-2-322. CTWALL will evaluate the overturning and sliding stability of a retaining or flood wall in accordance with the aforementioned criteria documents. This instruction report is organized to present CTWALL by describing the installation and equipment requirements, giving a general overview of the operation, discussing the interactive operation, describing the capabilities and procedures used in performing the stability analyses, and explaining the format to be used for a data file. The appendixes present examples and describe specific features of the program.

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